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NATURAL RESOURCE MANAGEMENT

Australian Government

2015-2020

Wet Tropics

Water Quality Improvement Plan

Wet Tropics Water Quality Improvement Plan: 2015-2020

Version 10 August 2015

Australian Government
Department of the Environment

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NATURAL RESOURCE MANAGEMENT

Contents

Acknowledgements

Terrain NRM and the project team would like to thank the Australian Government Reef Programme for providing funding to support preparation of the Wet Tropics Water Quality Improvement Plan (WQIP). We also recognise that the WQIP has benefited from the legacy of past investments associated with Reef Plan initiatives, industry and several research programs in the region.

The WQIP has been developed by Jane Waterhouse, Fiona Barron and Peter Bradley with a broad range of stakeholders and research providers over the last 12 months; every contribution has been greatly appreciated by the project team. In particular, we would like to acknowledge a number of individuals for their contributions: Neil Sing, Bruce Corcoran, Debra Harrison, Deb Bass, Sharlene Blakeney and Carole Sweatman (Terrain NRM); Travis Sydes and Darlene Irvine (FNQROC); Geoff Park (Natural Decisions); Marcus Smith and Mark Poggio (DAF); Louise Hateley (DNRM); Paul Groves and Donna Audas (GBRMPA); Jon Brodie, Steve Lewis, Jane Waterhouse, Len McKenzie and Colette Thomas (TropWATER); Brendan Ebner (CSIRO / TropWATER); Frederieke Kroon (formerly CSIRO, now AIMS); John Gunn (Earth Environmental); Ryan Turner (DSITIA); Matt Kealley (Canegrowers); Sean Hoobin and Glen Holmes (WWF). The contributions of Queensland Government and Australian Government stakeholders involved in the development of the WQIP are highly valued and their input and review of the WQIP has enhanced the relevance of the plan for implementation.

The draft Wet Tropics WQIP was circulated to over 80 stakeholders during two periods of review. The feedback we received has improved the final draft and we are grateful for the effort from individuals in their review. The final draft WQIP was also peer reviewed by three highly regarded experts: Roger Shaw, Di Tarte and Jim Binney. The project team would like to extend their personal gratitude to Roger, Di and Jim for their extremely helpful feedback.

Collaboration with other WQIP coordinators has also been beneficial and has assisted in continuing to progress a consistent approach to water quality improvement in the Great Barrier Reef at a regional scale.

Definitions and Abbreviations

Term	Definition
6ES:	Six Easy Steps; a framework used to describe a series of steps within a management system for sugar cane
Anthropogenic load:	Anthropogenic load is calculated as the difference between the long term average annual load and the estimated pre-European annual loads. A fixed climate period is used (1986 to 2009) for all model runs to normalise for climate variability and provide a consistent representation of pre-development and anthropogenic generated catchment loads. This therefore represents an 'average' year rather than the extremes such as those recorded in the period 2008 to the wet season in 2013.
COTS:	Crown of Thorns Starfish
COTS initiation zone:	Area where primary crown-of-thorns starfish (COTS) outbreaks have most frequently been observed. This area is assessed as the coral reefs between 14.5°S and 17°S (approximately between Lizard Island and Cairns) inside the GBR Marine Park boundary.
Chl-a:	Chlorophyll *a*
Coastal zone:	Area of coast as defined by the Queensland Coastal Plan 2011.
Coastal ecosystem:	Inshore, coastal and adjacent catchment ecosystems that connect the land and sea and have the potential to influence the health and resilience of the Great Barrier Reef. For this study, this includes the Wet Tropics NRM region within the Great Barrier Reef catchment and the Marine Park seawards of the coastline to a depth of 6 metres.
DIN:	Dissolved inorganic nitrogen
DIP:	Dissolved inorganic phosphorus
ERT:	Ecologically Relevant Targets
Ecosystem:	A dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit. Source: Millennium Ecosystem Assessment 2005.
Ecosystem function:	The interactions between organisms and the physical environment, such as nutrient cycling, soil development and water budgeting.
Ecosystem health:	An ecological system is healthy and free from distress if it is stable and sustainable - that is, if it is active and maintains its organisation and autonomy over time and is resilient to stress. Ecosystem health is thus closely linked to the idea of sustainability, which is seen to be a comprehensive, multi-scale, dynamic measure of system resilience, organisation, and vigour. This definition is applicable to all complex systems from cells to ecosystems to economic systems (hence it is comprehensive and multi-scale) and allows for the fact that systems may be growing and developing as a result of both natural and cultural influences.
Endemism:	Endemism is the ecological state of a species being unique to a defined geographic location, such as an island, nation, country or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere.
Environmental values (EVs):	Environmental values (EVs) are the qualities of waterways that need to be protected from the effects of pollution, waste discharges and deposits to ensure healthy aquatic ecosystems and waterways that are safe and suitable for community use. They reflect the ecological, social and economic values and uses (e.g. swimming, fishing, agriculture) of the waterway. http://www.ehp.qld.gov.au/water/policy/what_are_evs__wqos.html Environmental values (EVs) and water quality objectives (WQOs) have been scheduled (November 2014) by the Queensland Government for all Wet Tropics region surface and groundwaters under the Environmental Protection Policy (Water). http://www.ehp.qld.gov.au/water/policy/schedule1/wet_tropics_waters_scheduled_evs__wqos.html
Great Barrier Reef catchment:	The 35 river basins in Queensland which drain into the Great Barrier Reef.
HWMP:	Healthy Waters Management Plan
INFFER:	Investment Frameworks for Environmental Resources; www.inffer.com.au
Inshore marine areas:	Include (but not limited to) those areas extending up to 20 km offshore from the coast and which correspond to enclosed coastal and open coastal water bodies as described in the *Water Quality Guidelines for the Great Barrier Reef Marine Park (2009)*.
Lacustrine wetlands:	Lacustrine wetlands are large, open, water-dominated systems (for example, lakes) larger than 8ha. This definition also applies to modified systems (for example, dams), which are similar to lacustrine systems (for example, deep, standing or slow-moving waters). http://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/lacustrine/

Term	Definition
Natural Resource Management (NRM) regions:	A group of catchments managed by non-government organisations (NRM bodies) within Queensland. There are 56 NRM groups across Australia, and 14 in Queensland including 6 in the Great Barrier Reef catchments.
Natural Resource Management (NRM) bodies:	Non-government organisations funded primarily through government grants to run environmental and sustainable agriculture programs. In Queensland these groups are non-statutory, not for profit organisations.
Non-remnant vegetation:	Vegetation that does not meet the criteria of remnant vegetation as defined under the *Vegetation Management Act 1999*.
PAF:	Project Assessment Form, used as part of the INFFER assessment.
Palustrine wetlands:	All non-tidal wetlands that are substantially covered with emergent vegetation. Palustrine wetlands are primarily vegetated non-channel environments of less than 8 hectares. They include billabongs, swamps, bogs, springs, soaks etc, and have more than 30% emergent vegetation. http://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/palustrine/
PN:	Particulate Nitrogen
PP:	Particulate Phosphorus
Pollutants:	The WQIP refers to suspended (fine) sediments and nutrients (nitrogen, phosphorus) as 'pollutants'. We explicitly mean enhanced concentrations of, or exposures to, these pollutants, which are derived from (directly or indirectly) human activities in the GBR ecosystem or adjoining systems (e.g. river catchments). Suspended sediments and nutrients naturally occur in the environment; indeed, all living things in ecosystems of the GBR require nutrients, and many have evolved to live in or on sediment. The natural concentrations of these materials in GBR waters and inflowing rivers can vary, at least episodically, over considerable ranges. Pesticides do not naturally occur in the environment. Pollution occurs when human activities raise ambient levels of these materials (time averages, or event-related) to concentrations that cause environmental harm and changes to the physical structure, biological communities and biological functions of the ecosystem.
PSII herbicides:	Photosystem II-inhibiting herbicides
PSU:	Practical Salinity Units; used to report salinity in sea water.
Pre-clear:	Queensland government reconstruction of regional ecosystems to represent vegetation pre-European settlement.
Post-clear:	Queensland mapping of the state of Regional Ecosystems that occurred in 1999 and 2009.
Reef 2050 LTSP:	Reef 2050 Long Term Sustainability Plan http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan
Remnant vegetation:	Vegetation that meets all of following criteria: • 50 per cent of the predominant canopy cover that would exist if the vegetation community were undisturbed • 70 per cent of the height of the predominant canopy that would exist if the vegetation community were undisturbed • composed of the same floristic species that would exist if the vegetation community were undisturbed.
Regional Ecosystem:	Regional Ecosystems (REs) are vegetation communities that are consistently associated with a particular combination of geology, land form and soil in a bioregion. The Queensland Herbarium has mapped the remnant extent of regional ecosystems for much of the State using a combination of satellite imagery, aerial photography and on-ground studies. Each regional ecosystem has been assigned a conservation status which is based on its current remnant extent (how much of it remains) in a bioregion. Some areas of Cape York have not been mapped.
Resilience	Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004).
River basins:	A *River basin* is the portion of land drained by a river and its tributaries where surface water channels to a hydrological network (i.e. river, stream, creek) and discharges at a single point. Australia has 245 numbered drainage basins or Queensland has 76 basins. *A basin is also referred to as a catchment (or a watershed).*
Sub-basin:	Smaller catchment drainage area situated within a river basin
TSS:	Total suspended solids

Term	Definition
Vulnerability:	The degree to which a system or species is susceptible to, or unable to cope with, adverse effects of pressures. Vulnerability is a function of the character, magnitude, and rate of variation or change to which a system or species is exposed, its sensitivity, and its adaptive capacity.
WQIP:	Water Quality Improvement Plan
Water quality objectives:	Water quality objectives (WQOs) are long-term goals for water quality management. They are measures, levels or narrative statements of particular indicators of water quality that protect environmental values (EVs). WQOs define what the water quality should be to protect the EVs—after consideration of the socio-economic assessment of protecting the water quality. WQOs can be defined for a range of physical, chemical, biological and waterway condition measures. WQOs to support environmental values (EVs) have been scheduled by the Queensland Government for all Wet Tropics waters, and are available from the EHP website.
Land use classifications:	Land-use groupings are an amalgam of common land use (LU) categories that follow the ALUM classification (version 6) and are provided by the latest QLUMP (2009; latest available) GIS maps shown in the table below.

Land Use classification	General description	ALUM codes
Conservation	Conservation & natural environments	1 (all classes)
Open grazing	**Livestock grazing -** *Split livestock grazing using SLATS FPC (20%) into open and forested grazing* Grazing modified pastures Native/exotic pasture mosaic Land in transition Irrigated modified pastures Irrigated land in transition Abandoned intensive horticulture Dairy sheds & yards	2.1.0 3.2.0 3.2.1 3.6.0-3.6.5 4.2.0 4.6.0-4.6.5 5.1.4 5.2.1
Forested grazing	**Livestock grazing -** *Split Livestock grazing using SLATS FPC (20%) into open and forested grazing* Woody fodder plants	2.1.0 3.2.2
Sugar cane	Dryland + irrigated sugar	3.3.5, 4.3.5
Bananas	Provided from an external source to Louise Hateley and only used in Wet Tropics model	
Forestry	Production forestry Plantation forestry	2.2.0, 2.2.1 3.1.0-3.1.4
Dryland cropping	Cropping (except sugar), includes cropping, cereals, beverage and spice crops, hay & silage)	3.3.0-3.3.3
Irrigated cropping	Irrigated cropping (except Irrigated Sugar 4.3.5) includes irrigated (where relevant): cereals, beverage and spice crops, hay & silage, oil seeds & oleaginous fruit, cotton, alkaloid poppies	4.3.0-4.3.7
Horticulture	Perennial horticulture Seasonal horticulture Irrigated perennial horticulture Intensive horticulture	3.4.0-3.4.7 3.5.0 4.4.0-4.5.5 5.1.0-5.1.3
Water	Water areas	6 (all classes) 0.0.0
Urban		5.4.0-5.4.4
Other	Intensive animal production (where relevant, includes intensive animal production, cattle feedlots, poultry farms, piggeries, aquaculture, other intensive animal husbandry, Manufacturing and industrial Farm buildings and infrastructure Services	5.2.0, 5.2.2-5.2.9 5.3.0-5.3.8 5.4.5 5.5.0-5.5.5

Term	Definition		
		Utilities	5.6.0-5.6.6
		Transportation and communication	5.7.0-5.7.5
		Mining	5.8.0-5.8.4
		Waste treatment and disposal	5.9.0-5.9.5
Organisations			
AIMS:	Australian Institute of Marine Science		
CSIRO:	Commonwealth Science and Industrial Research Organisation		
DAF:	Queensland Department of Agriculture and Fisheries		
DEHP:	Queensland Department of the Environment and Heritage Protection		
DNRM:	Queensland Department of Natural Resources and Mines		
DoE:	Department of the Environment		
DSITI:	Queensland Department of Science, Information Technology and Innovation		
FNQROC:	Far North Queensland Regional Organisation of Councils		
GBRMPA:	Great Barrier Reef Marine Park Authority		

Summary

Scope (Chapter 1)

- This Water Quality Improvement Plan (WQIP) has been developed to address requirements established under the Australian Government's Reef Programme and follows guidance for the Queensland Healthy Waters Management Plans (HWMPs) specified in section 24 of the *Environmental Protection Policy (Water) 2009* (EPP Water). Where WQIPs adequately address matters specified under the EPP Water for HWMPs, they may be accredited as HWMPs[1].
- The Wet Tropics landscape has been heavily modified since European settlement, resulting in changes to hydrological connectivity and ecological functions like material trapping, filtering and diversion. Modifications include large scale changes in land use to activities that generate greater pollutant loads, particularly in coastal areas. One of the main consequences of these changes is degraded water quality which poses a significant threat to the health of the Wet Tropics catchment waterways, coastal and marine ecosystems. Accordingly, the Wet Tropics WQIP adopts two main management strategies:
  1. Directly reduce pollutant runoff through management practice improvements
  2. Restore the ecological function of the landscape through 'system repair' actions

Water quality issues in the Wet Tropics region (Chapter 2)

- Water quality determines the suitability of water for several purposes and is essential to our social and economic well-being, and environmental health. Water supports people, agriculture, animals and plants, and is central to the health of the whole ecosystem as it connects places, processes and species. The protection and improvement of water quality sustains economic and social activities and ensures ecological health for present and future generations. In the Wet Tropics there are many highly valuable ecological systems, including the internationally recognised Great Barrier Reef World Heritage Area (GBRWHA) and Wet Tropics World Heritage Area (WT WHA).
- In recent years, a great deal of effort has been made by governments and the community to enhance water quality in the Great Barrier Reef (GBR), primarily through catchment management. Regional WQIPs are part of the Queensland and Australian Government's Reef Water Quality Protection Plan (Reef Plan) which are designed to identify targeted approaches to water quality issues at a regional level. Reef Plan 2013 states that its long term goal is "to ensure that by 2020 the quality of water entering the reef from broadscale land use has no detrimental effect on the health and resilience of the Great Barrier Reef."
- The Wet Tropics WQIP is designed to identify the main issues impacting catchment waterways and the coastal and marine environment from land-based activities, and to identify and prioritise management actions that will halt or reverse the trend of declining water quality within the Wet Tropics region. It describes the current state of water quality issues in the region including catchment waterways, coastal ecosystems and the GBR. The WQIP identifies the priority water quality and ecosystem health issues for the region in terms of which pollutants pose the greatest risk to key assets, primary pollutant sources and hotspots for pollutant generation and delivery. It highlights the importance of the region in the crown of thorns starfish phenomenon, one of the major causes of coral mortality across the GBR. For the first time regionally specific end of catchment pollutant load targets are defined to maintain the coastal and marine values of the region (ecologically relevant targets). The WQIP also identifies catchment waterways of greatest ecological value in the region, and establishes priority areas for improving or rehabilitating the ecological function and health of these ecosystems. An Implementation Plan identifies the priorities and actions for achieving the proposed targets in the most cost-effective manner.
- All land uses in the region are considered in the WQIP, however, there is a focus on sugar cane in the cost-benefit analysis for achievement of the pollutant load targets. This is largely due to lack of information about the water quality benefits and cost effectiveness of management practices in other industries in the region.

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[1] The HWMP guidelines are available from the department's website at http://www.ehp.qld.gov.au/water/policy/water_quality_improvement_plans.html

- The area of interest is the Wet Tropics Natural Resource Management (NRM) region, and the adjacent coastal and marine area. There are nine major river basins in the region; from north to south they are; Daintree, Mossman, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert.
- The Wet Tropics WHA covers 35% of the region, which has provided a degree of protection to the integrity of the catchment waterways. However, a high proportion of freshwater ecosystems in the coastal areas outside of this protected estate and within developed land uses such as agriculture and urban areas are assessed to be in a moderately or highly modified state. This is particularly evident in the central and southern basins of the region. Key threats are associated with altered hydrology, loss of connectivity, loss and disturbance of habitat, decline in water quality and soil chemistry, introduction of pest species and extraction such as fishing. It is not possible to determine the cumulative effects of all impacts but the interaction of multiple processes and the overarching influence of climate change also present considerable threats to the Wet Tropics waterways.
- Assessment of the current status of key marine and coastal assets in the Wet Tropics region has identified a number of assets that are in poor or very poor condition. These include: inshore and mid-shelf coral reefs, inshore and reef seagrass meadows, dugong populations, low-lying islands, and species of climate sensitive seabirds. Key drivers of change include poor water quality largely driven by catchment land uses, crown of thorns starfish (COTS) outbreaks (which are linked to poor water quality), climate extremes (floods, cyclones, thermal coral bleaching), coastal development including ports and shipping, and the cumulative impacts of these pressures. It is well established that improving water quality will help to improve the resilience of our environmental assets to other stressors.

Priority pollutants and key sources (Chapter 3)

- The largest sources of pollutants to the GBR are from agricultural land uses, and are usually diffuse rather than arising at point sources. However, other sources include activities and wastes associated with intensive animal production, manufacturing and industry, mining, rural and urban residential, transport and communication, waste treatment and disposal, ports/ harbours, and shipping. Compared to diffuse sources, point source contributions are relatively small but could be locally intense and over short time periods highly significant. Point sources are generally regulated activities.
- The pollutants of greatest concern to water quality in the GBR are total suspended solids (TSS), dissolved inorganic nitrogen (DIN) and photosystem II inhibiting herbicides (PSII herbicides). Dissolved inorganic phosphorus (DIP), particulate nitrogen (PN) and particulate phosphorus (PP) are also of concern but less is known about their biological transformation and ecological effects on ecosystems in the region.
- The modelling indicates that a large proportion of the total load in the region is derived from anthropogenic (human induced) changes, with the following proportions of anthropogenically derived loads: TSS 60%, DIN 42%, DIP 2%, PSII 100%, PN 49%, PP 17%.
- Within the Wet Tropics region, the Johnstone and Herbert basins are the highest contributors of the total loads for all of the pollutant load constituents that have been modelled (TSS, DIN, PSII herbicides and particulate nutrients).
- Grazing land use is the greatest source of TSS in the region (32% of the total TSS load). However, on a land use by area basis, cropping land uses tend to have a higher generation rate per unit area. The model estimates indicate that the Herbert basin contributes the greatest anthropogenic TSS load in the region, and is almost double the amount contributed from any other basin.
- Sugar cane land use is the greatest source of DIN (42% of the total DIN load and ~80% of the anthropogenic DIN loads) and PSII herbicides (>95%) in the region, and accounts for a large proportion of intensive land uses in the region. However, on a land use by area basis, it is estimated that bananas generate the highest areal load of DIN per hectare, but the amount varies considerably between basins depending on local characteristics such as management practices, slope and rainfall. Model estimates indicate that the Johnstone basin contributes the greatest anthropogenic DIN loads in the region, accounting for ~42% of the total regional load. The Herbert basin contributes the greatest PSII herbicide loads in the region at approximately 28% of the regional load.
- The Russell-Mulgrave, Johnstone, Tully, Murray and Herbert basins are the highest priority areas for reducing pollutant loads to the GBR in the Wet Tropics region.

Pollutant load reduction targets (Section 3.3)

- End-of-system load reduction targets for the major pollutants of concern are defined in Reef Plan 2013. Regionally specific load targets have since been derived in addition to the development of ecologically relevant end of catchment load reduction targets for all of the Wet Tropics basins. Ecologically relevant targets (ERTs) attempt to define acceptable pollutant load values that would be required to meet the GBR Water Quality Guidelines, which propose to be suitable to maintain ecosystem health based on current system understanding. Meeting ERTs is required to continue to achieve the overall long-term Reef Plan goal of ensuring: "that by 2020 the quality of water entering the reef from broad scale land use has no detrimental effect on the reef's health and resilience". Water Quality Objectives for open coastal/marine waters have been based on the better of current water quality (as interpreted and analysed by GBRMPA), or the GBR Water Quality Guidelines (GBRMPA, 2010). Hence the ERTs referred to in this document for marine waters may have local variations from the WQOs scheduled in the EPP (Water).
- A critical knowledge gap is setting freshwater and coastal ecosystem targets that factor in the asset and functional values of these systems, and the values of reducing or halting the threats on the freshwater values. These values and threats are further described in Section 5. An example of this gap is correlating the removal of a percentage of fish barriers and blockages within a system and how that activity will improve the health of the Reef or the catchment. Investment into research that will assist in target setting needs to occur. For this iteration of the WQIP, the targets in freshwater and coastal ecosystems in the Wet Tropics are the environmental values (EVs) and water quality objectives (WQOs) were scheduled in November 2014 by the Queensland Government for all Wet Tropics region surface and groundwaters under the Environmental Protection Policy (Water) 2009. Documents and plans are available from the EHP website at: http://www.ehp.qld.gov.au/water/policy/schedule1/wet_tropics_waters_scheduled_evs__wqos.html.
- Based on current evidence, it is proposed that a feasible timeframe for achievement of the ERTs is approximately 20 years from now, i.e. 2035. Beyond this period, the influence of water quality improvement in the context of other drivers of GBR health such as climate change make gains in water quality improvement difficult to predict. Additionally, external factors such as agricultural expansion, intensification of agricultural land uses, or/and increased pressure from coastal development have not been factored into this; these are also likely to modify the feasibility of the proposed timeframe.

Management practice options (Section 3.4)

- To inform the choice of management options, knowledge about the best choice of management practices for improving water quality outcomes in the Wet Tropics region was collated. These are translated into focus areas for each of the key land uses in the region in Table ii and largely draw on information collated in Sing and Barron (2014) and Gunn (2014).

Assessment of options to meet the targets (Section 4)

- Modelling of land-use adoption scenarios across the entire GBR has shown that complete adoption of B class management practices in grazing and sugar cane may be sufficient to meet the Reef Plan targets for PSII herbicides, but are well below the proposed reductions required to meet the Reef Plan and proposed ERTs for suspended sediment, nitrogen and phosphorus. Based on these assessments, it is evident that it will be challenging to meet the 2018 Reef Plan targets and the longer term ecologically relevant targets with the current suite of agricultural management practices. Accordingly, extension and education programs and research and development to investigate innovative practices are critical for implementation of the WQIP over the next 5 to 10 years. In addition, restoration of ecological functions in the floodplain and coastal ecosystems will also be critical; however, the likely benefits of these restoration activities are yet to be quantified and have been highlighted as a knowledge gap in the WQIP.
- Knowledge of the current adoption of management practices is critical in assessing the likelihood of meeting the pollutant load reduction targets. Present knowledge indicates that a large proportion of the area under sugar cane in the region is managed to a standard that is below the current definition of best management practice (B class practices). Detailed adoption data for other industries is limited, with the exception of those areas where incentive payments have been provided which is a relatively small proportion of the total area.
- The INFFER analysis conducted for sugar cane in the Wet Tropics WQIP considered a number of scenarios that could be implemented in sugar cane to achieve the DIN and PSII herbicide load reductions required to meet the ecologically relevant targets (over a 20 year period). The results are shown in Table i. Note that A class practices are considered to be innovative and not yet fully proven, B class practices are considered best practice, and C and D classes are below best practice standards (see full definitions in section 3.4.1).

Table i. Results of the INFFER analysis for sugar cane management projects in the Wet Tropics region, based on Reef Plan targets. Red indicates that Reef Plan targets are not met; green indicates that Reef Plan targets could be met. Source: Park and Roberts, (2014a).

Sugar cane Case – based on 5 years	Annual funding required in the first 5 years ($M)	Benefit: Cost Ratio (BCR)*	Predicted DIN reduction (RP Target 50%)	Predicted PSII reduction (RP Target 60%)
A. All A practice	6.6	0.49	~30%	~95%
B. 50% A: 50% B	5.8	0.54	~24%	~79%
C. All B practice	2.6	1.3	~19%	~63%

Note: A Benefit: Cost Ratio of 1 is cost-neutral, >1 indicates greater benefit than cost and <1 indicates a greater cost than benefit.

Broadly, the analysis indicates that shifting all growers to A class practices comes at a significant cost to growers and would require considerable investment and extension support ($6.6M per year). A shift to all A class practices meets the PSII herbicide targets (both Reef Plan and ecologically relevant targets) but only achieves 60% of the Reef Plan DIN target, and less than 50% of the DIN ecologically relevant target. Shifting all growers to B class practices appears profitable to growers. While full adoption of class B practices is predicted to meet the Reef Plan PSII herbicide targets, the anticipated load reduction falls well short of the Reef Plan DIN targets and are far below the ecologically relevant targets. Basin specific scenarios indicate that shifting to All B practices in the Johnstone basin is the most cost effective option (BCR 3.1; supported by extension and training, and assuming that no financial incentives are required).

- Priorities are also identified among the basins. Six basins are equally very high priority for action to reduce pollutant loads to the GBR. These basins are: Johnstone, Tully/Murray, Herbert and Russell/Mulgrave. The dominant land use associated with DIN and PSII herbicide loads in these basins is sugar cane. Basin-specific social and economic characteristics related to current management practice adoption, farm size and therefore the economic feasibility of practice change influence the feasibility of reducing pollutant load reductions in each basin. These are summarised in Table iii, and explained further in Section 8). Based on this, **the Johnstone and Tully-Murray basins currently appear to be the highest priority basins for practical targeting of investment in sugar cane practice improvement.**

Restoring ecological function of catchment waterways and coastal ecosystems (Chapter 4, Section 5)

- Preliminary results of a region-wide assessment of the values and threats to freshwater ecosystems and coastal ecological function and connectivity in the Wet Tropics region are presented. The approach to the assessment is consistent with other prioritisation tools developed in the Wet Tropics and is being used as a spatial planning framework. The Wet Tropics System Repair Spatial Planning Framework includes the definition of a set of management objectives and responses that will ultimately be identified for each basin and where appropriate, at a smaller local scale in 2015-2016.
- The management objectives are based on the outputs of an aggregate value/threat matrix for the region, plus the ability to determine management responses that can be based on individual values and individual threats. Options are presented to Protect, Restore, Maintain or Adapt landscapes depending on current condition and threats. Further effort is required to validate and develop the framework to inform the development of a system repair strategy for the Wet Tropics region.
- It is assumed that actions to directly reduce pollutant loads and actions that restore ecosystem functionality will be required to reduce water quality pressures on the GBR and build the resilience of the coastal and inshore ecosystems to other pressures such as a changing climate and increased development. Knowledge about techniques for the restoration of coastal ecological functionality and the associated benefits is highlighted as a priority for future research to support long term management of the GBR. Better understanding of these concepts will enable us to make trade-offs between investments in pollutant load reductions and coastal ecosystem restoration.

Adopting a holistic approach to water quality management in the Wet Tropics (Chapter 5, Section 6 to 10)

- Implementation of the WQIP will require actions across a range of land uses including agricultural and urban areas, and areas where ecological functions such as water retention, sediment trapping and hydrological connectivity have been heavily modified. Changes to the management of agricultural land to improve the water quality of runoff, and actions that restore coastal ecological function will be required across all basins.
- The Implementation Plan for the WQIP recommends a combination of:
  - Financial incentives to encourage management practice improvements;
  - Extension programs to facilitate technology transfer, education, communication, demonstrations and to provide support for community networks;
  - Technology change including of improved land management options, such as through strategic research and design (R&D), participatory R&D with landholders, and provision of infrastructure to support new management options; and
  - Regulation and policy instruments where appropriate.

  Results from existing initiatives in the region associated with Reef Plan 2013 such as the Australian Government Reef Programme water quality grants, and training and extension programs, will form a strong basis to these actions. However, these commitments currently only continue up to 2018, and current water quality grants funding ends in June 2016.
- Implementation Plans have been drafted for each basin in the Wet Tropics region. These contain management outcome targets, management actions, estimated costs, identification of the lead agency or partners, and identification of relative priorities within each basin.
- The preferred strategy for management practice improvement in sugar cane is to shift all growers to B class practices as a minimum standard in all basins (as the most cost effective option) and to support further investment into innovative practices. This investment in innovation may be in several forms including funding of R&D projects, development of specialised grants or the provision of technical support to individual trials. Priority basins have been identified for targeting effort for pollutant load reduction in the region.
- For all industries other than sugar cane (as outlined above), the WQIP adopts the relevant Reef Plan target region-wide, which requires that 90% of the area of each industry in each basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. Beyond 2018, at minimum, these levels must be maintained. These targets will be reviewed in line with the broader Reef Plan review at that time.
- A draft management practice framework has been incorporated for point source and diffuse source including for developing and mature urban areas and public and private sector development urban areas. More work needs to be done to arrive at a 'final' system that relates all the individual actions to produce a reporting system that is practical and useful for organisations involved in urban stormwater management including the implications for water quality, costs and benefits and the level of improvement required for each practice for each classification.
- It is recommended that implementation of system repair actions occurs in several, phased steps:
  - Planning and consultation to identify the priority areas for management intervention in the context of the Management Objectives identified in the Wet Tropics System Repair Spatial Planning Framework.
  - Implementation of a set of short term (1 to 2 year) 'no regrets' system repair projects.
  - Development of a regional system repair strategy to deliver regional outcomes for supporting coastal ecosystem function and landscape connectivity.
  - Implementation of larger scale priority projects across the region.
- A monitoring and evaluation strategy has been developed to support implementation of the WQIP and facilitate an adaptive management approach to the delivery. On-going revision of the knowledge underpinning the WQIP and the most appropriate management approaches will be critical to ensure that optimal water quality outcomes can be achieved for the region.
- A profile for each basin is being prepared that summarises the key characteristics identified above into a report card format at a basin scale. This summary assists to define basin-specific issues and management options, and will support implementation at a smaller scale. These profiles will also form the basis for periodic review of the WQIP. Note that these profiles are available in draft form and will be finalised in 2015.

Challenges

The collation of information to support the WQIP highlights a number of significant challenges. One of these is to develop an integrated understanding of the benefits of pollutant load reductions combined with the benefits of activities that aim to restore ecological functionality in the floodplain and coastal ecosystems. Current understanding of the linkages between coastal ecosystem functionality and water quality outcomes is conceptual, and is yet to be quantified. However, it is probable that activities that restore ecological functions such as hydrological connectivity and retention of water in the floodplain, will have downstream water quality benefits, at least in moderate flow events (there is limited retention time in the floodplain in high flow events), as well as more substantial benefits for system functions such as productivity and connectivity. In the WQIP, it is assumed that both sets of actions will be required to reduce water quality pressures on the GBR and build the resilience of the coastal and inshore ecosystems to other pressures such as a changing climate.

The other significant challenge is the fact that the current suite of management actions is not adequate to meet the Reef Plan pollutant load targets. It is clear that unparalleled levels of funding, commitment to improving the science (especially integration with economics), the need to take action now whilst managing adaptively, and investing in an increasingly strategic and targeted fashion will be required if agricultural and coastal development impacts on the catchment and marine ecosystems of the Wet Tropics are to be managed. While many trajectories are possible, the following principles are likely to be needed to maintain some of the existing values of the freshwater, coastal and marine ecosystems through reducing agricultural and coastal development impacts at the scale that will be required, and in a way that makes best use of limited funding in an efficient and accountable manner. It is suggested that the following factors need to have been addressed if the GBR is to be protected as well as possible by 2050:

- Performance goals/targets which means including an agreed cap on total pollutant discharges. This would need to be supported by improved conceptual understanding of the likely ecosystem health responses.
- Clear rules, responsibilities and accountability of institutions to ensure that there is a clear pathway for achieving the agreed performance goals and targets, including public and timely reporting of successes and failures.
- Establishment of baseline nutrient discharges and development of appropriate metrics to enable industries (agricultural and urban) to respond to ecosystem signals and funding opportunities.
- Well considered and long term best practice policy approaches based on public and private net benefits. This is likely to require a mix of incentives, extension, research and underpinning regulations for different sectors.
- Long term funding to support research (development of improved technologies and long-term commitment to modelling) and monitoring programs to gauge progress and manage adaptively, develop management options in agricultural sector and understand coastal and riparian ecosystem functions and connectivity roles to Reef health.
- Long term constructive commitment of government, industry and environmental stakeholders to understand perspectives, respect differences and work collaboratively.

These factors are relevant at a GBR wide scale, and it is clear that an incremental, largely ”business as usual” approach will not address the challenges facing the GBR.

A preliminary estimate of the likely cost of implementation of the WQIP is also outside of the scope of current funding for water quality improvement in the GBR and its catchments. Current estimates indicate that an investment of at least $6 million per year would be required to fully implement the actions identified within the Wet Tropics WQIP. However, this only factors in planning actions for system repair and no on-ground works which would need to be addressed beyond the first 12 to 18 months. It also assumes that incentives would not be required to shift to agricultural practices which are demonstrated to be profitable, which may be unrealistic, at least in the first 2 to 3 years. While a portion of the investment is already covered through existing programmes, there is limited resource commitment beyond June 2016 to support implementation. This includes enabling actions such as project management, communications, monitoring and evaluation, a number of high priority research projects, actions to directly reduce pollutant loads (sugar cane and all other agricultural industries) and a strategy for commencing a system repair program for the Wet Tropics. Some of these items could be most cost effectively undertaken as collaborative projects across the GBR, with benefits to multiple policy platforms including Reef Plan and the Reef 2050 Long Term Sustainability Plan.

Table ii. Strategies for progressing achievement of pollutant reduction targets in the Wet Tropics region. These are summarised from Section 3.4. Note that A class practices are considered to be innovative and not yet fully proven, B class practices are considered best practice, and C and D classes are below best practice standards.

Land use / Strategy	Focus Actions Dissolved Inorganic Nitrogen[2]	PSII Herbicides	Suspended Sediment / Particulate Nutrients	Approach for Implementation
Sugar cane ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices.* *Research and development to support innovation in management practice* ***Priority Basins:*** **Russell-Mulgrave** **Johnstone** **Tully-Murray** **Herbert**	Very High Priority 1. Adoption of Smartcane BMP framework as industry minimum standard (and minimum legislative standards). 2. Optimise fertiliser (N) application to reduce N surplus and increase nitrogen use efficiency. Target the amount used and timing, and to a lesser extent its placement. 3. Variable rate application through identification of georeferenced soil zones (Precision Agriculture) to reflect block yields and soil characteristics. 4. Encourage adoption of whole farm management systems amongst farmers and contractors.	Very High Priority 1. Target timing of herbicide application (no application within 30 days of wet season commencement – implies greater use of forecasting). 2. Residual use in plant crops and ratoons. 3. Banded spray applications. 4. Hooded sprayers. 5. Row spacing	Low Priority 1. Target controlled traffic farming. 2. Target best practice drainage management.	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practices (georeferenced soil zones, whole farm management systems). • Encourage farmers to move along a path where initially they use 6ES based on 120% of district yield, then with-in mill area districts, followed by farm yields, block yields then with-in block yields. This approach would be combined with the impact on yield of time of harvest, stage in crop cycle, proximity to the start of the wet season and age of crop. • Training course of risks of N losses and the management options. Targeting larger cane farms in conjunction with one-on-one extension. Target 170 management units with farms greater than 200 ha which covers 60% of the land under cane. • Extension to encourage tailored nutrient rates for high risk locations, time of the year, late harvested crops and parts of the crop cycle. • Provision of incentives supported by long-term property management agreements (until improved technology improves practices to become profitable in their own right).

[2] Many of these strategies are also relevant to managing phosphorus.

Land use / Strategy	Focus Actions Dissolved Inorganic Nitrogen[2]	PSII Herbicides	Suspended Sediment / Particulate Nutrients	Approach for Implementation
				• Auditing and reporting program to ensure compliance with management agreements. • R&D into slow release fertilisers, innovative fertiliser reduction schemes.
Bananas ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Russell-Mulgrave** **Johnstone** **Tully-Murray**	High Priority 1. Optimise fertiliser application through fertigation. 2. Use of slow release fertilisers to complement fertigation. 3. Use of permanent beds and block contouring 4. Liaison with extension officers and farm-consultants regarding recommended nutrient application rates	Limited use 1. Best practice inter row maintenance	Moderate Priority 1. Target permanent beds, contour banks and improved maintenance of the inter row	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides.
Mixed cropping and other horticulture **Strategy:** *Research and development to address knowledge gaps in terms of practices, practice effectiveness and costs* ***Priority Basins:*** **Barron**	Low Priority	Use depends on crop	Moderate Priority 1. Target contour banks, minimum tillage, controlled traffic and grassed headlands as a package of works.	• Use extension to promote sediment management as a package of practices that complement each other and support this by WQ grants to provide incentives.
Dairy ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Barron**	Low Priority 1. Use of slow release fertilisers.		Low Priority 1. Fencing to exclude access to riparian areas and streambanks, and installation of off-stream watering sites.	
Grazing	Low Priority	Limited use	High Priority Key sources: Streambank and hillslope erosion	• Work with owners of properties that have been shown to have low levels of ground cover over the last ten years to reduce stocking rates which should in

Land use / Strategy	Dissolved Inorganic Nitrogen[2]	Focus Actions PSII Herbicides	Suspended Sediment / Particulate Nutrients	Approach for Implementation
Strategy: *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Herbert**			1. Retention of ground cover at the end of dry season 2. Stocking rates consistent with regional benchmarks and property characteristics 3. Strategies implemented to recover land in poor or very poor condition and target erosion hotspots. 4. Fencing off rilled areas, gullies, riparian and sodic soil areas. 5. Best practice road maintenance and construction, and fence line clearing.	the longer term produce higher returns for those graziers. Training course on soil health. • Training course on best practice road and fence construction.
Urban **Strategy:** *Adoption of improved practices in urban development* *Priority Basins:* **Barron** **Russell-Mulgrave**	Moderate Priority 1. Continue to investigate options for sewage effluent reuse	Low Priority	Moderate priority *Developing areas* 1. Erosion and sediment control 2. Water Sensitive Urban Design *Mature urban areas* 1. Stormwater management	• Consultation with local government to target soil erosion and subsequent movement of sediment to waterways during the development phase, particularly on sloping sites as well as floodplains and flat sites especially in close proximity to waterways. • Focus on new developments due to large costs associated with retrofitting. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.
Other land uses				
Disused mine sites in the Upper Herbert *Priority Basins:* **Herbert**			High priority	These actions require further consideration and discussion with relevant stakeholders in 2015.

Table iii. Summary of management approaches, estimated costs and extension effort for DIN and PSII herbicide load reductions from sugar cane in the Wet Tropics region. Note: [1]Cost estimates are based on the INFFER analysis, and are likely to be conservative as it is assumed that incentives will not be required to facilitate practice shifts which are shown to be profitable. Refer to Section 8 for further explanation.[2] Parts of the analysis are conducted for the combined Russell-Mulgrave catchment.

Basin	Priority /DIN Adoption Strategy	DIN Management Approach	PSII Adoption Strategy / Priority	PSII Management Approach	Shift to All B practices ($M/yr)[1]			Extension effort to 2016				
					Upfront cost over 5 yrs	Annual mainten-ance cost	BCR	No. of growers	Growers receiving grants	Growers DIN priority	Minimum T&D delivery outcomes	Proportion of growers targeted
Daintree-Mossman	Medium Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Low Minimum All B	No Incentives, High extension & training	0.3	0.3	1.20	68	19	22	41	60%
Barron	Low Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Low Minimum All B	No Incentives, Moderate extension & training	0.3	0.3	0.3	60	18	1	19	32%
Russell[2]	High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Medium Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	0.9	0.9	0.8	283	100	71	171	60%
Mulgrave	High Minimum All B; aim for at least 25% A	High Incentives, High extension & training										
Johnstone	Very High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	0.9	0.9	3.10	172	89	30	119	69%
Tully-Murray	Very High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	1.2	1.2	1.27	200	71	66	137	69%
Herbert	High All A desirable; aim for min. 50% A	Moderate Incentives, High extension & training	High All A desirable; aim for min. 50% A	Moderate Incentives, High extension & training	2.9	2.9	0.22	580	156	84	240	41%
Total								1,363	453	274	727	53%

Chapter 1: Background and Introduction

1. Introduction

1.1 Background

Water quality determines the suitability of water for several purposes and is essential to our social and economic well-being, and ecological health. Water supports people, agriculture, animals and plants, and is central to the health of the whole ecosystem as it connects places, processes and species. The protection and improvement of water quality sustains economic and social activities and ensures ecological health for present and future generations. In the Wet Tropics there are many highly valuable ecological systems, including the internationally recognised Great Barrier Reef (GBR) and Wet Tropics World Heritage Area (WT WHA).

Prior to European settlement, the GBR catchment was covered with woodlands, grasslands and forests, and coastal floodplain and wetland systems. These land-based elements can act as natural filtering systems or traps for sediment and nutrients that run off from the land when it rains. The delivery of pollutants from the GBR catchments to the GBR has changed because of the removal or modification of these natural systems, resulting in more sediments and nutrients running into the GBR over time and introduction of new pollutants including pesticides. These catchment areas adjacent to the GBR have also undergone extensive development for agricultural production, urban expansion, transport infrastructure, tourism and mining. These land use changes have also had a negative impact on water quality in the freshwater, coastal and marine systems of the GBR and its catchments. It is now widely recognised that the quality of water flowing into the GBR lagoon from the land has deteriorated dramatically over the past 150 years (Brodie et al., 2013a). These changes can be detected using historic data such as coral coring and geochemical records (e.g. Carilli et al., 2009; Lewis et al., 2012).

Different parts of the GBR are exposed to different degrees of influence from land-sourced pollutants. At a GBR-wide scale, primary pollutant sources include suspended sediment from erosion in cattle grazing areas and to a lesser extent runoff from cultivated areas in cropping; nitrate from fertiliser application on crop lands; and herbicides from various land uses (Brodie et al., 2013a). The fate and effects of these pollutants in the receiving marine environment are relatively well understood (see Schaffelke et al., 2013). When assessing the relative risk of these pollutants, Brodie et al., (2013b) concluded that the greatest water quality risks to the GBR are from nitrogen discharge leading to crown-of-thorns starfish outbreaks and their destructive effects on coral reefs, and fine sediment discharge which reduces the light available to seagrass ecosystems and inshore coral reefs. Pesticides pose a risk to freshwater and some inshore and coastal habitats.

In recent years, a great deal of effort has been made by governments and the community to enhance water quality in the GBR, primarily through catchment management. The Queensland and Australian Government's Reef Water Quality Protection Plan (Reef Plan[3]) initially established in 2003 and revised in 2009 and 2013, provides the foundation for this effort. Reef Plan 2013 states that its long term goal is "*to ensure that by 2020 the quality of water entering the reef from broadscale land use has no detrimental effect on the health and resilience of the Great Barrier Reef*." The Plan includes the deliverable of '*a Water Quality Improvement Planning process (aligned with Healthy Waters Management Plan guideline under the Environment Protection Policy Water) to consider Reef Plan's long term goal and use of consistent modelling information to set regional and subregional water quality and management action targets that align with Reef Plan'*. In August 2013, the Australian Government's Reef Programme committed to funding a Water Quality Improvement Plan (WQIP) for the whole Wet Tropics region. Continued investment towards a water quality grant program for the region has also occurred through the Australian Government's Reef Programme (formerly Reef Rescue), guided by the region's existing WQIPs (Douglas, Barron and Tully-Murray).

Environmental values (EVs) and water quality objectives (WQOs) have been scheduled (November 2014) by the Queensland Government for all Wet Tropics region surface and groundwaters under the *Environmental Protection Policy (Water) 2009*. Documents and plans are available from the EHP website at: http://www.ehp.qld.gov.au/water/policy/schedule1/wet_tropics_waters_scheduled_evs__wqos.html

[3] http://www.reefplan.qld.gov.au/

The Wet Tropics Natural Resource Management (NRM) region has been identified as a high risk region in terms of the influence of degraded water quality on GBR ecosystems (Brodie et al., 2013b, Waterhouse et al., 2012). In the most recent relative risk assessment of degraded water quality on the GBR (Brodie et al., 2013b), the Wet Tropics region was ranked as the highest risk NRM region compared to other regions. This ranking was largely associated with loads of nutrients and pesticides that are delivered to the GBR from the catchments in the region, and the influence of the region's river flow and nutrient load on the initiation of the outbreak of Crown of Thorns Starfish (COTS) populations. In addition, the midshelf and offshore reef complex is located relatively close to the coast in the Wet Tropics region in comparison to southern areas of the GBR (Figure 1.1), which results in regular exposure of these ecosystems to river plumes during the wet season (typically November to May). The framework from this assessment has now been applied at a regional scale to inform Wet Tropics regional water quality management issues at a basin scale (Waterhouse et al., 2014).

1.2 Water quality planning in the Wet Tropics NRM region

The Wet Tropics NRM region is one of six NRM regions in the GBR catchment (Figure 1.1). The Wet Tropics of Queensland World Heritage Area covers 35% of the region (and 86% of the WHA is within the region) and the coastal and marine areas are part of the GBR World Heritage Area (GBRWHA) and Marine Park. The NRM region has an approximate catchment area of 22,000 km^2 and is approximately 5% of the total GBR catchment area (423,134 km^2) (Hateley et al., 2014). There are nine Australian Water Resources Council river basins that make up the region (ANRA, 2002). From north to south they are Daintree, Mossman, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert (Figure 1.1). The Mulgrave and Russell basins are combined into one reporting basin as the two rivers join upstream and discharge as a single waterway to the coast. The marine NRM region (as defined by the Great Barrier Reef Marine Park Authority [GBRMPA]; see Figure 1.1) extends seawards from the northern and southern boundaries of the NRM region, to the outer edge of the GBRWHA, and has an area of approximately 32,000 km^2. However, this is an administrative boundary and does not necessarily reflect the extent of influence of the catchments on the marine environment in the region. Furthermore, large catchments south of the Wet Tropics NRM region such as the large Burdekin River influence the marine ecosystems adjacent to the NRM region.

With funding from the Coastal Catchments Initiative, three catchment-scale WQIPs were developed in the Wet Tropics between 2006 and 2009: Douglas WQIP for the Daintree-Mossman catchments (Davis, 2005), Tully WQIP for the Tully-Murray catchments (Kroon, 2008; Terrain NRM, 2008) and the Barron-Trinity WQIP for the Barron River/Trinity Inlet (Barron and Haynes, 2009). These WQIPs were prepared consistent with the *Framework for Marine and Estuarine Water Quality Protection and the National Water Quality Management Strategy.*

A process to develop Healthy Waters Management Plans (HWMPs) for the remaining Wet Tropics catchments commenced in 2010 (see Section 1.5). Environmental Values were developed for the remaining Wet Tropics catchments (the Mulgrave, Russell, North and South Johnstone, and Herbert). This process was run in collaboration with the Queensland Government Wet Tropics Water Resource Plan process which states that under the *Water Act 2000* a Water Resource Plan must consider the EVs. The intent was to develop a Regional HWMP which incorporated the existing WQIPs which is essentially incorporated into this Wet Tropics WQIP process. This WQIP has been developed to address requirements for HWMPs specified in section 24 of the *Environmental Protection Policy (Water) 2009*. 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 EHP website at http://www.ehp.qld.gov.au/water/policy/water_quality_improvement_plans.html.

This Wet Tropics WQIP has been developed in partnership with industry, government, science and community and builds on the three existing catchment-scale WQIPs and the HWMP outcomes, integrates with the Regional NRM Plan and incorporates aspirations from, and informs the revision of, community-based catchment plans.

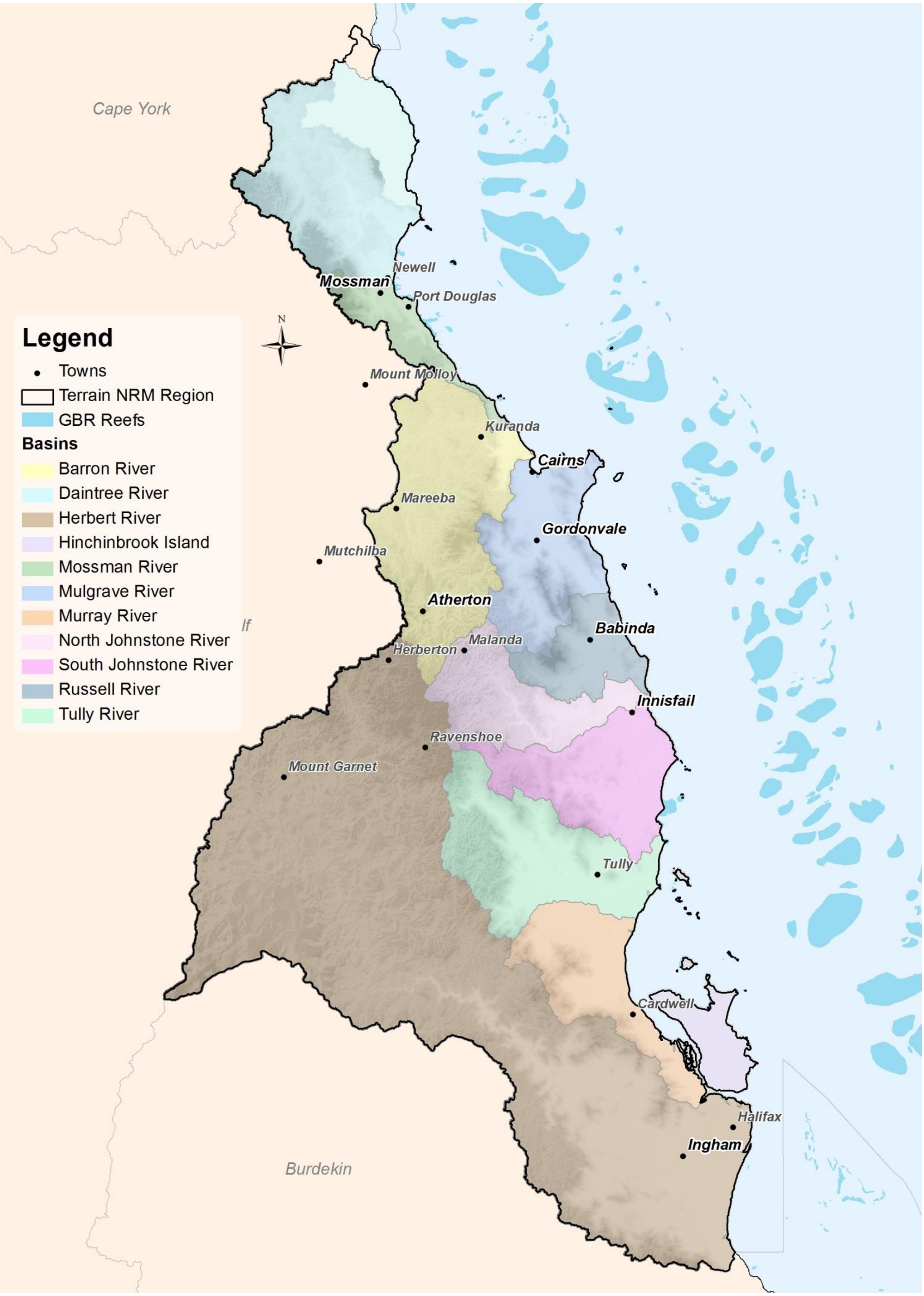

Figure 1.1. The Wet Tropics Natural Resource Management region.

1.3 Scope and aims of the Wet Tropics WQIP

A WQIP is designed to identify the main issues impacting waterways and the coastal and marine environment from land-based activities, and to identify and prioritise management actions that will halt or reverse the trend of declining water quality within a region. More specifically, the Wet Tropics WQIP provides a framework to:

1. Describe the current state of water quality and identify water quality issues in the region.
2. Identify the priority water quality and ecosystem health issues for the region, in terms of:
   - current water quality values highlighting those that are in decline or threatened, and key pollutant drivers, spatially and by sector;
   - desired water quality environmental and use values that the community aspires to protect/enhance;
3. Estimate the implications and costs of intervention options (including status quo) based on least cost risk abatement:
   - identify key pollutants to be reduced and key sources (sectoral and practices);
   - estimate annualised pollutant delivery at end of catchment (and where available, sub catchment scale), progressing to estimates of loss to catchment waterways and groundwater as information becomes available;
   - develop pollutant reduction targets to maintain the desired in-stream, coastal and marine values of the region; and
   - as information becomes available, map the risk of off-site pollution at the smallest practical scale, and estimate and map as applicable production efficiency (yield/inputs) and pollution intensity (unit production/pollution eg. nutrient, TSS, pesticide).
4. Define regional end of catchment pollutant reduction targets to maintain the coastal and marine values of the region.
5. Define waterways of greatest ecological value in the region, and establish priority areas for protection, restoration, maintenance or adaptation of the ecological function and health of these areas.
6. Estimate and clearly document the effectiveness of current management interventions.
7. Develop and compare abatement costs for intervention options to protect desired values.
8. Develop an implementation strategy in consultation with government, industry and community groups for managing water quality in the region and achieving the proposed targets, through identification of management practices and projects that can be adopted to meet targets and objectives in the most cost effective manner. This will guide strategic investment in water quality issues in the region for the next 5 to 10 years. Strategies for long term planning consistent with the Reef 2050 Long Term Sustainability Plan are also incorporated.
9. Develop and agree with stakeholders on a robust, adaptive, relevant and transparent monitoring, evaluation and reporting and review framework for progress at all scales to ensure public accountability and community support for long term re-investment in water quality protection, by the least cost interventions.

The scope of the Wet Tropics WQIP is illustrated in Figure 1.2. The plan contains two major system components which interact to deliver a holistic approach to water quality management in the Wet Tropics region: the catchment waterways and freshwater ecosystems and then the receiving waters of the GBR coastal and marine environments.

The region's economy is highly dependent on a healthy environment with high quality functioning ecosystems. Many industries generate substantial income for the region either directly or indirectly related to the environment, including a very significant contribution from environmental tourism to the region's economy. Whilst the focus of the WQIP is predominantly on agriculture, which is identified as the greatest source of diffuse pollutants, it is recognised that other industries and activities are also a source of pollutants and have the potential for adverse impacts on water quality. Many of these industries are outside the scope of this WQIP but are managed through either their own industry codes of practice or legislated regulations. Legislation is applicable for many industries that are associated with point sources of potential pollutants for example, aquaculture and many urban industries including wastewater treatment. Other primary industries are strictly regulated for example, forest timber harvest or commercial fishing. Mining, another heavily regulated industry, is of particular significance for the Herbert catchment where there are extensive areas under exploration leases but is an industry beyond the scope of this WQIP.

The WQIP provides recommendations for management activities that will further improve water quality and freshwater ecosystems but these actions are identified in a singular fashion. That is, an activity and the expected benefits are discussed independent of other activities when in reality none of these activities occur in isolation. The cumulative outcomes of many combined activities and potential synergistic impacts of multiple pollutants, require further attention, and are a major consideration of the Strategic Assessments and Outlook Reports recently completed for the GBR (GBRMPA, 2014a,b).

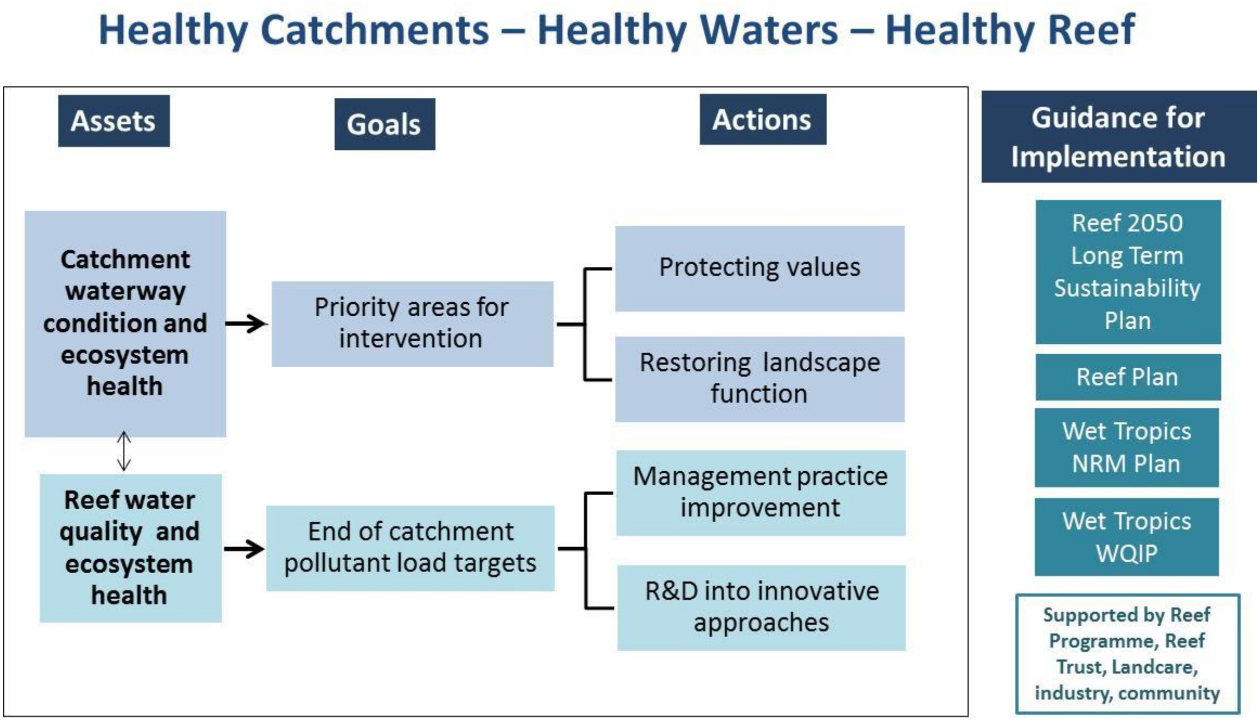

Figure 1.2. The scope of the Wet Tropics WQIP, showing the two major components of catchment waterway condition and ecosystem health, and Reef water quality and ecosystem health.

1.4 The structure of the Wet Tropics WQIP

This WQIP is presented in several sections.

Chapter 1: Background and Introduction
Section 1: Introduction

Chapter 2: The characteristics of the Wet Tropics region
Section 2: Water in the Wet Tropics

- Environmental and economic values
- Regional characteristics for population, climate, land use
- Current status, trends and threats of Wet Tropics waterways and receiving waters

Chapter 3: Strategy 1: Reducing pollutant runoff from the Wet Tropics basins
Section 3: Pollutant sources, management priorities and targets

- Key pollutants and sources
- Priority areas for reducing pollutant runoff
- Pollutant load reduction targets
- Management options for directly reducing pollutant loads

Section 4: Analysis of options for achieving pollutant reduction targets

- Analysis of options for achieving pollutant reduction targets

Chapter 4: Strategy 2: Restoring catchment waterways and ecological function in the Wet Tropics basins
Section 5: Assessing values, threats and management options for catchment waterway health and ecological function

- Identifying and assessing Environmental Values
- Defining high value waterways and key threats
- Assessing regional priorities
- Management options

Chapter 5: Adopting a holistic approach to water quality improvement in the Wet Tropics: Implementation **Plan and delivery options**
Section 6: Delivery Mechanisms
Section 7: Wet Tropics in 2050
Section 8: Implementation Plan
Section 9 Reasonable Assurance Statement
Section 10: Monitoring Evaluation and Reporting

Guiding water quality management in the Wet Tropics at a basin scale (Basin profiles)
A profile for each basin is being prepared that summarises the key characteristics identified above into a report card format at a basin scale. This assists to define basin-specific issues and management options, and will support implementation at a smaller scale. These profiles will also form the basis for periodic review of the WQIP.

1.5 Approach to developing the plan

Using existing knowledge and information

The Wet Tropics WQIP has built on the existing WQIPs in the region and the draft Healthy Waters Management Process (2012). The WQIPs are prepared consistent with the *Framework for Marine and Estuarine Water Quality Protection* (2002), and apply the framework described in the National Water Quality Management Strategy (NWQMS, 1992[4]). In Queensland, this is linked through the *Environmental Protection Act 1994* which is the main legislation for water quality in freshwater, estuarine and marine areas, and includes the *Environmental Protection (Water) Policy 2009* (EPP Water, 2009) and *the Environmental Protection Regulation 2008* (EPR, 2008) (Kroon et al. 2014). The EPP (Water) provides targets for water quality management through the development of environmental values, and water quality guidelines and objectives under the framework provided by the National Water Quality Management Strategy (NWQMS, 1992) at a catchment scale. The Environmental Protection Regulation provides a regulatory regime for Environmentally Relevant Activities that have the potential to impact on water quality, including, but not limited to agriculture, aquaculture, mining, and waste disposal. The Environmental Protection Act also sets monitoring requirements related to release of wastewater at a regional and local scale. WQIPs and HWMPs are prepared to meet relevant requirements, including HWMP requirements specified in section 24 of the *Environmental Protection Policy (Water) 2009*.

In the Wet Tropics region, comprehensive consultation processes have been undertaken to establishEVs and WQOs for the region. These are categorised in Table 1.1. The outcomes and process for defining these values is outlined in a report by Terrain NRM in 2012[5], and in November 2014, the EVs and WQOs for all surface and groundwaters in the region were scheduled under the EPP Water.

Several guidelines are available for maintaining water quality in the region. These include:

- The Great Barrier Reef Water Quality Guidelines (2010) (GBRMPA, 2009).
- The Queensland interim biological guidelines for Wet Tropics coastal streams: Aquatic macro invertebrates (Negus et al., 2013).
- Groundwater and surface water quality guidelines – Wet Tropics region (Department of the Environment and Heritage Protection [DEHP], 2014).

These guidelines are applied through various planning controls and policies by local and Queensland government agencies. It is the role of the WQIP to identify where these are most relevant for protecting or improving the water quality of the region.

Additional legislative and policy context that is relevant to the development and implementation of the WQIP is included in Appendix 1.

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[4] National Water Quality Management Strategy, Australian Government Department of the Environment. http://www.environment.gov.au/water/quality/national-water-quality-management-strategy.
[5] Terrain (2012) Consultation Report: Environmental Values for the Wet Tropics Basins. Further copies of the report may be obtained from www.terrain.org.au using the link http://www.terrain.org.au/programs/water/water-quality/617-healthy-water-management-plan.html.

Table 1.1. Environmental Values and Questions from Stakeholder Workshops in the Wet Tropics region. Source: Terrain NRM (2012).

Environmental Value	Supporting Details	Questions
HUMAN USES		
Primary Industries	**Irrigating** crops such as sugar cane, mangoes, avocadoes, hay	**Where is the water used for irrigation? What crops, etc. are irrigated?**
	Water for **farm use** such as in fruit packing, milking sheds, vehicle wash-down, piggeries, feedlots	**Where is the water used around farms for washing down areas or fruit packing?**
	Stock watering	**Where is the water used for watering stock? What type of stock?**
	Water for **aquaculture** such as prawns, barramundi	**Where is the water used in aquaculture operations and what species are cultivated?**
	Human consumption of stocked fish or crustaceans	**Where is there consumption of wild or stocked fish or crustaceans**
Recreation & Aesthetics	**Primary recreation** with direct contact with water e.g. swimming, snorkelling, wading	**Are there any recreational activities where people are fully immersed in the water e.g. swimming, snorkelling? If so, where?**
	Secondary recreation with indirect contact with water e.g. sailing, canoeing, boating, rafting	**Are there any recreational activities where people are possibly splashed with water e.g. fishing, boating, sailing? If so, where?**
	Visual appreciation no contact with water e.g. bushwalking, picnicking, sightseeing	**What areas of waterways are regularly used by people who enjoy looking at and being near the waterway?**
Drinking Water	**Raw drinking water** supplies	**Where do people or local governments take water from the river for water supplies?**
Industrial uses	Water for **Industrial Use** e.g. power generation, manufacturing plants	**What are the industries that take water from the river for their operations and where does it occur?**
Cultural& Spiritual	**Cultural and Spiritual** values	**What are the cultural and spiritual values associated with the waterways?**
Aquatic ecosystems	**Pristine or modified Aquatic Ecosystems**	

Building the evidence base

Terrain NRM has adopted the principle of utilising the best available knowledge for the development of the WQIP, and commissioned a number of supporting science studies to assist in building this current information base. The studies are grouped into four main areas, and are listed in Table 1.2.

1. Freshwater ecosystems, catchment condition and system repair
2. Regional prioritisation and ecological targets
3. Developing management actions
4. Foundation monitoring activities

Each of the studies informs one or several steps in the development of the WQIP. Figure 1.3 illustrates how the studies fit into the overall WQIP framework, derived from the National Water Quality Management Strategy.

The supporting studies have generated standalone reports which have been independently peer reviewed to inform the WQIP, and are available on the Terrain NRM website (http://www.terrain.org.au/Projects/Water-Quality-Improvement-Plan/Studies-and-Reports). The key findings have been incorporated into the plan where relevant.

Table 1.2. Summary of the supporting studies commissioned to assist Terrain NRM in the development of the Wet Tropics WQIP.

Supporting studies	Delivery Partner / Consultant	Project Leaders *Report Reference*
1. Freshwater ecosystems, catchment condition and system repair		
a) Spatial prioritisation, mapping and analysis across region for Systems Repair	FNQROC GBRMPA	Travis Sydes Paul Groves, Donna Audas
b) State of the freshwater ecosystems	CSIRO, TropWATER	Frederieke Kroon, Seonaid Philip, Brendan Ebner, James Donaldson *Kroon et al. (2014)*
2. Regional prioritisation and ecological targets		
a) State of the marine environment review	C_2O Consulting	Johanna Johnson *Johnson (2014)*
b) Wet Tropics risk assessment and investment prioritisation. Includes specific studies on end-of-catchment pollutant loads, pesticides in cropping areas and screening of pollutants in sewage discharges.	TropWATER, JCU AIMS DNRM	Jane Waterhouse, Jon Brodie, Steve Lewis Richard Brinkman Louise Hateley *Waterhouse et al. (2014), O'Brien et al. (2014), Brinkman et al. (2014), Hateley et al. (2014)*
c) Ecologically relevant targets and evaluation of ecosystem values	TropWATER, JCU AIMS	Jon Brodie, Steve Lewis, Colette Thomas Scott Wooldridge *Thomas and Brodie (2014); Brodie et al. (2014)*
d) Sediment sources in Upper Herbert	Ian Little	Ian Little *Little (2014)*
3. Developing management actions		
a) Review of agricultural management practice options in the region.	Terrain NRM	Neil Sing, Fiona Barron *Sing and Barron (2014)*
b) Assessment of urban management options. Assessment informed by GBR wide Smart Urban Water Management project, and the development of guidance materials for Water Sensitive Urban Design	FNQROC Water by Design	Darlene Irvine John Gunn, Dave Logan *Gunn et al. (2014)*
c) Analysing and selecting management options: INFFER assessment and economic analysis	Natural Decisions DAF	Geoff Park Marcus Smith *Park and Roberts (2014a, b)*
4. Foundation monitoring activities		
a) Seagrass monitoring Hinchinbrook Channel and Russell Mulgrave	TropWATER JCU	Len McKenzie *McKenzie et al. (2014)*
b) Russell Mulgrave sub catchment monitoring	DSITI Terrain NRM	Ryan Turner Michael Nash

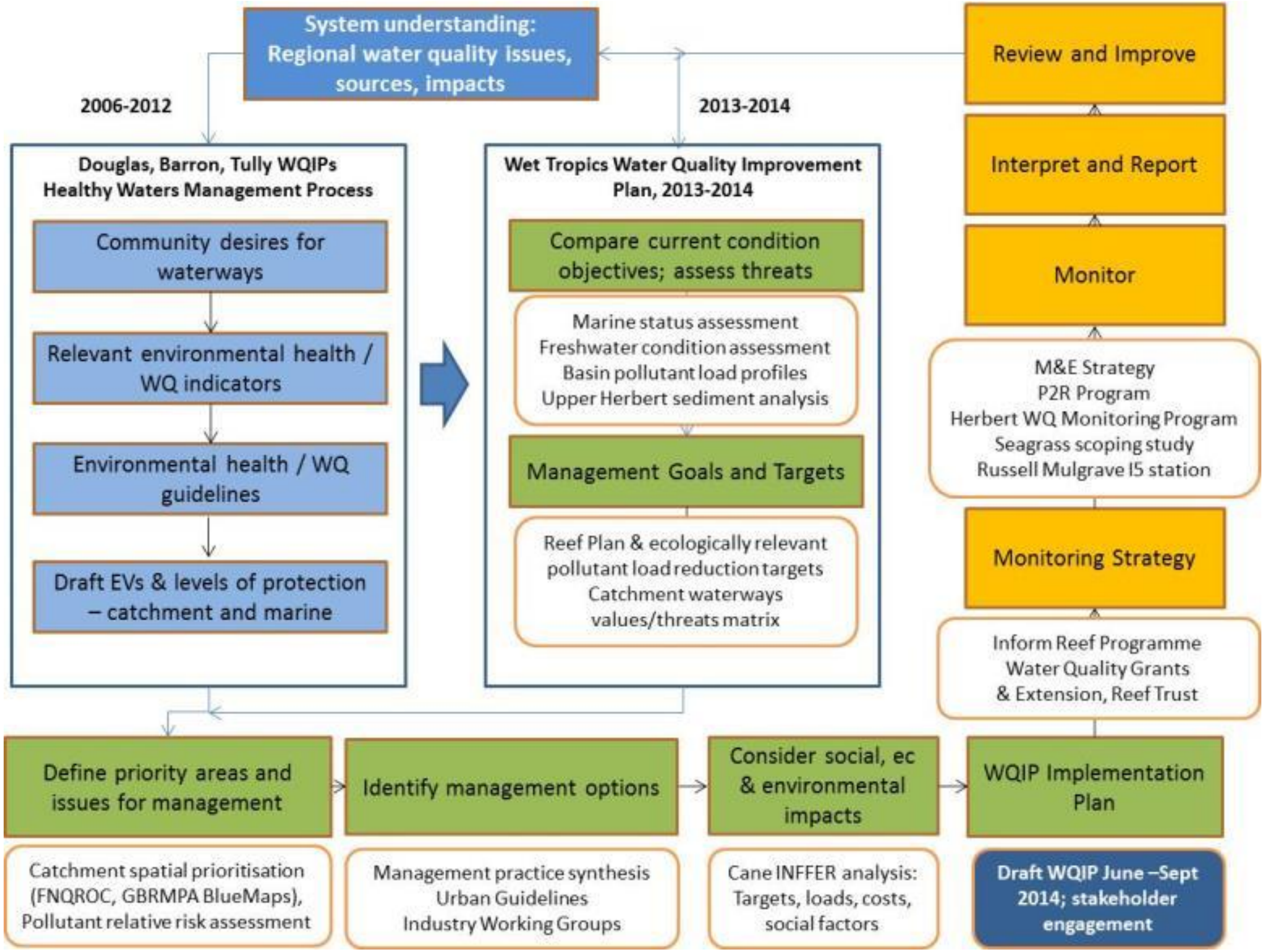

Figure 1.3. The overarching framework for the Wet Tropics WQIP informed by a number of supporting studies. The light blue boxes indicate steps completed as part of the previous WQIP and HWMP planning processes, green boxes indicate current work, and orange boxes represent future steps (over 5 years).

1.6 Technical advice and stakeholder engagement

Technical advice

To support the development of the Reef Water Quality Protection Plan 2013 (Reef Plan 2013) a multidisciplinary group of scientists, with oversight from the Reef Plan Independent Science Panel, was established to review and synthesise the significant advances in scientific knowledge of water quality issues in the GBR and to reach consensus on the current understanding of the system. Many of these same scientists have been engaged to prepare supporting studies for Wet Tropics WQIP (see Table 1.1) and as part of the WQIP process these experts contributed to two workshops for the INFFER process. A number of Terrain NRM staff involved in regional activities and stakeholder representatives were also involved and are listed in Appendix 2. This group was engaged in the review of the draft WQIP.

The major focus for management with regard to receiving waters relates to activities associated with sugar cane and to a lesser extent, bananas. Terrain NRM coordinates two Industry Working groups – one Cane Industry Working Group and a Banana Industry Working Group. Both of these groups were engaged in the development and review of the WQIP, although to a lesser extent with the banana group due to limited availability during this period. Interaction with other agricultural industries representatives has been targeted through meeting with Terrain's Industry Advisory Group which incorporates representatives from the cane, tropical fruit, grazing and tourism industries.

Consultation

In recognition of the extensive work and engagement processes that have already occurred across the region with regard to planning and consultation and water management, it was decided to approach consultation and engagement in two main phases. A Consultation Strategy was established to outline this process.

The first phase, early in the process and at a less intense level, aimed to raise awareness of the overall WQIP process. Information published on the Terrain website included a WQIP FAQ sheet and a one-pager of basic WQIP information[6]. The FAQ was provided to Terrain partnership staff to distribute to their stakeholders at local meetings. Presentations were given on opportunistic occasions, based around already scheduled catchment and Landcare group meetings.

The second phase of consultation and engagement for the WQIP was more detailed and focused on communicating the content of the draft WQIP. This was undertaken from August to October 2014 through Terrain's industry working groups (sugar cane, bananas and a multi-industry representative group), local and regional catchment organisations, peak industry bodies, government agencies (local, State and Commonwealth) and the GBR Local Marine Advisory Committees. A formal schedule was developed to ensure that the opportunity for engagement across a range of stakeholders occurred. The purpose of the consultation was to communicate the goals and management intent for the region, describe how management actions were prioritised and explain the science informing these decisions. This phase sought stakeholder feedback, particularly whether or not there were any major oversights with regard to issues or actions.

Traditional owner values associated with water and water quality have been considered in several planning processes in the region in recent years including the previous WQIPs, the Healthy Waters Management planning process and the Water Resource Plan. These processes have captured and reiterated the information that "*All water bodies (ground waters, fresh waters and salt waters) have high importance for Rainforest Aboriginal peoples. This includes spiritual, cultural, aesthetic, fishing and recreation values*". These values have been formally incorporated into the individual basin profiles in this WQIP. In terms of particular management activities, traditional values are recognised in the restoration of catchment waterways, coastal ecosystems and ecological function. It is anticipated the input of traditional owners will form a critical contribution to further development of high priority proposals for these activities.

Terrain NRM continues to engage with local government through the FNQROC regional meetings, the Reef Urban Stormwater Management Improvement Group (RUSMIG), and the Local Marine Advisory Committees which also include representatives from other industries such as tourism, commercial fishing and aquaculture.

The WQIP forms an integral part of the review of the Wet Tropics NRM Plan. The review involves extensive consultation with the community which will also be used opportunistically for the WQIP. A short video with interviews of key scientists presenting key information about the WQIP is available via the Terrain NRM website[7] and was utilised for consultation and general public information.

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[6] Download from: http://www.terrain.org.au/Projects/Water-Quality-Improvement-Plan

[7] http://www.terrain.org.au/Projects/Water-Quality-Improvement-Plan

Chapter 2: The characteristics of the Wet Tropics region

2. Water in the Wet Tropics region

2.1 A highly valuable and diverse region

The Wet Tropics region contains unique, diverse and highly valuable terrestrial and aquatic environments and is unique in having two World Heritage Areas side by side - the Wet Tropics and Great Barrier Reef World Heritage Areas.

The Wet Tropics rainforests are recognised internationally for their ancient ancestry and many unique plants and animals, including the oldest continuously surviving tropical rainforests on earth[8]. Many plant and animal species in the Wet Tropics are found nowhere else in the world and the diverse range of vegetation communities are habitat to numerous rare and threatened species. The Wet Tropics is also recognised on the World Heritage list for its exceptional natural beauty, with superlative scenic features highlighted by extensive sweeping forest vistas, wild rivers, waterfalls, rugged gorges and coastal scenery.

The region is also recognised for its diverse and unique freshwater, coastal and marine environments including rivers and streams, wetlands, estuaries, coral reefs, seagrass meadows, continental and cay islands and the species they support. Some of these species are listed as threatened or vulnerable, and have significant cultural values (Johnson, 2014; Kroon et al., 2014). These ecosystems also support important tourism and fisheries industries that depend on the healthy natural resources of the region.

The region is highly valuable from a social and economic perspective, and in providing ecosystem services. Thomas and Brodie (2014) have reviewed these characteristics for the GBR ecosystems to conclude that the Wet Tropics region has the highest monetary value in the GBR, driven to a large extent by its sizeable reef-specific tourism industry. Reef-specific tourism in the Wet Tropics region has an estimated value of A$248m (approximately 37% of the total GBR reef-specific tourism monetary value). The region contributed 24% of the monetary value of recreation in the GBR. The value of commercial fishing is estimated at A$18m, which is only 10% of the total GBR monetary value of this activity.

In the catchment, agricultural land uses are of critical importance to the regional economy. However, there are several limitations to reporting regional statistics due to differences in administrative boundaries used for the ABS Census. Within these limitations Marsden Jacob Associates (2013) has estimated that in 2005-06 the region provides an economic contribution from agriculture (including cane, bananas, paw paws, livestock-slaughtering and products and forestry), of more than $800m annually. Cane contributes approximately $300m of this value, and grazing is approximately $230m annually. Basin-specific contributions to these values vary across the region, with the Barron contributing $205.3m, Russell-Mulgrave $77.8m, Johnstone $218.3m, Tully-Murray $126m and Herbert $178.8m. Supporting services for agriculture engage many more people in transport, processing and marketing activities.

About 300,000 people live in or within 50km of the Wet Tropics World Heritage Area and it receives about 2.5 million visits per year from locals and tourists. In 2008 it was estimated that visitation to the WTWHA contributed $2,058 million in annual direct and indirect output or business turnover; $927 million in annual direct and indirect value added, $607 million in annual direct and indirect household income; and 13,351 direct and indirect jobs (Gillespie Economics and BDA Group, 2008).

2.2 Regional characteristics

2.2.1 Population and coastal development

The region supports a population of over 250,000 people, including more than 20,000 local indigenous Rainforest Aboriginal people, in a number of urban and rural centres. Cairns is the largest population centre (~157,000 resident people), with other larger coastal centres including Innisfail, Cardwell and Ingham as well as many smaller towns

[8] http://www.wettropics.gov.au/wet-tropics-world-heritage-values

located along the coast and throughout the catchments. Larger inland centres including Mareeba, Atherton, Malanda, Ravenshoe, Herberton and Milla Milla are located on the Tablelands.

2.2.2 Climate and geography

The Wet Tropics region has two distinct climatic seasons (wet and dry), with the majority of rainfall falling in the wet season (December to March). Rainfall is dominated by major events such as rain depressions, monsoons and cyclones. Regional rainfall averages 1,580 mm, with an approximate range of 500 - 4,500 mm (Figure 2.1). There is a strong rainfall gradient westwards from the coast, partly due to orographic effects of the coastal mountain ranges, with average annual rainfall of approximately 3,000 mm on the coastal fringe declining to 500 mm at the western edge of the region. The wettest meteorological station in Australia is located on Mt Bellenden Ker (in the Russell-Mulgrave basin) and receives an annual average rainfall of 8,000 mm (Queensland Government 2011). Both the Herbert and Barron basins have significant inland areas of relatively low rainfall (<1000 mm per annum), as well as wetter coastal fringes.

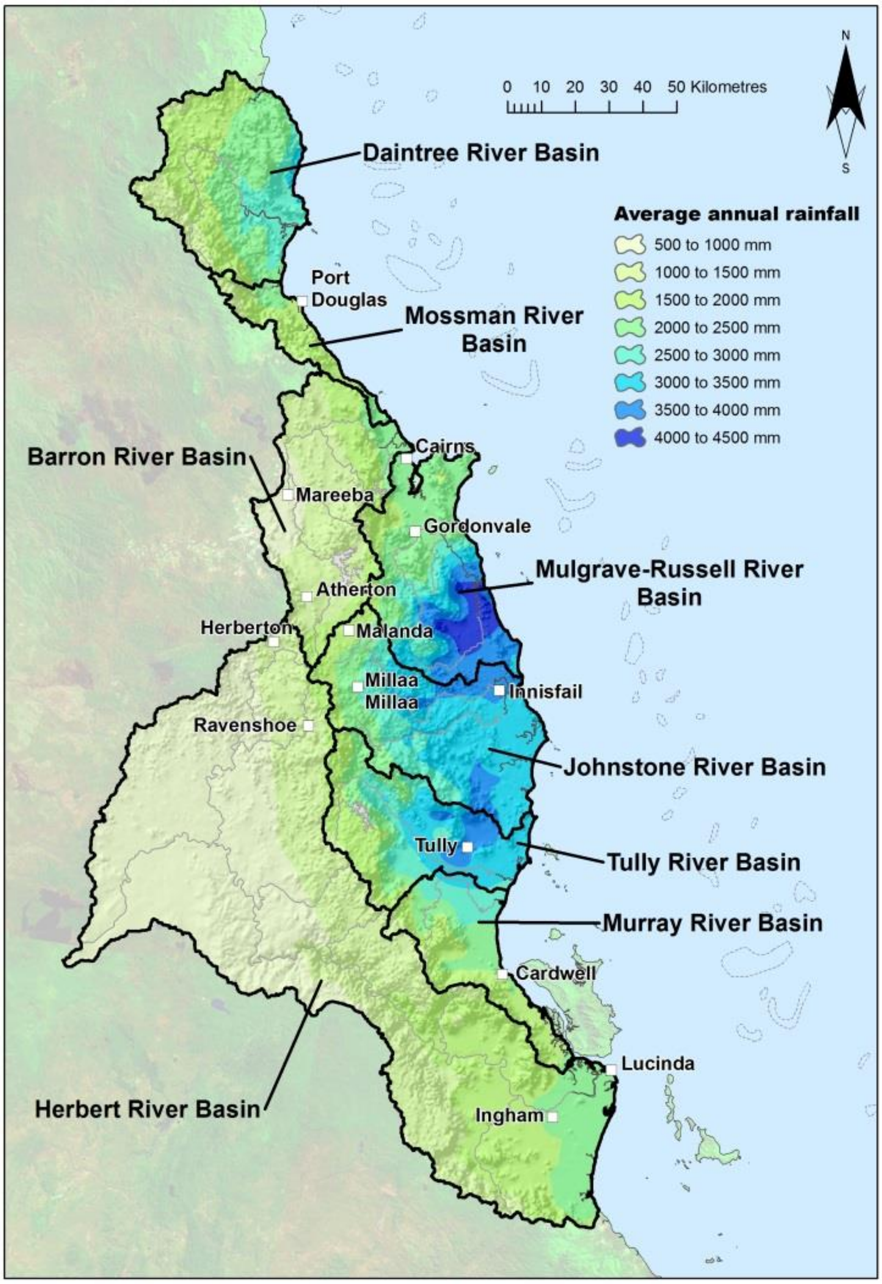


Figure 2.1. Spatial distribution of Wet Tropics average annual rainfall. Source: Hateley et al. (2014).

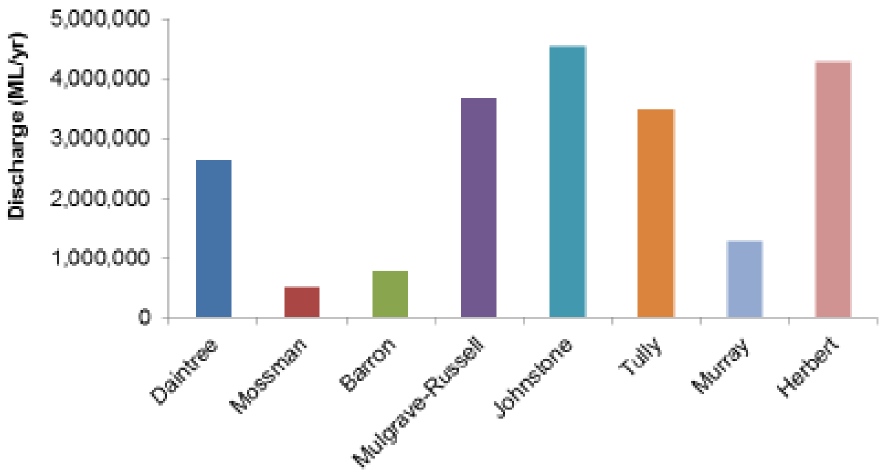
The region is characterised by high relief mountains located close to the coast resulting in a narrow coastal plain (McDonald and Weston, 2004). Tablelands and ranges are located in the west on the Great Escarpment and these areas contain large outcrops of basalt. These features, combined with high rainfall results in rivers with large discharges and high streamflow velocities (DEH and DNR, 1999). The movement of sediment, nutrients and herbicides is largely controlled by the volume, intensity and distribution of rainfall (Furnas, 2003). For the majority of Wet Tropics basins, more than half of the rainfall leaves as runoff from the soil surface, mostly during the large wet season events. Other factors such as topography, soils and vegetation greatly influence the amount of rainfall moving as runoff (Furnas, 2003).

River discharge varies between the Wet Tropics basins as shown in Figure 2.2. Long term median annual flows are greatest in the Herbert River, followed by the Johnstone, Russell-Mulgrave and Tully. Figure 2.3 shows that annual variability is significant, but generally follows the same patterns in terms of relative flow discharges to the GBR.

The Wet Tropics is unique compared to the other GBR regions as it has the highest annual flow volume with 33% of the flow to the GBR from only 5% of the GBR contributing land area. This is illustrated in Figure 2.4, which also shows the inter-annual variability within and across the GBR regions. In the smaller catchments such as the Tully, several flood events (of varying size) commonly occur within a wet season. The time between rainfall and runoff is short in the Tully as large storms can occur over the whole basin and the distance from headwaters to the coast is small (Furnas, 2003). In contrast the larger drier catchment such as the Herbert, most runoff occurs as a single wet season flood, but a major flood may not occur every year (Furnas, 2003).

The time from rainfall to runoff to discharge is short in the Wet Tropics compared to the larger GBR basins such as the Fitzroy and Burdekin. This rapid timeframe results in limited loss of dissolved nutrients and herbicides by in-stream or floodplain processes before being transported into the GBR lagoon in floods. Streams flow all year round in the major Wet Tropics rivers due to frequent rainfall and groundwater inputs. For example, there is less difference in annual discharge in the Tully River compared to the highly seasonal Burdekin River in the dry tropics, primarily due to more constant discharge in the Tully River (Furnas, 2003).

Figure 2.2. Annual average discharge (ML/yr) for Wet Tropics basins (1986-2009). Source: Hateley et al. (2014).



The three dominant soil types found in the region are dermosols (including non-sodic chromosols/kurosols/kandosols), ferrosols and rudosols/tenosols (Hateley et al., 2014). Dermosols are the most widespread soils in the region and occur mostly in the humid coastal area, forming on a wide range of geologies and terrain and are commonly quite fertile. These are the areas mostly used for cropping. Dermosol soils are considered to be moderately to highly erodible depending on slope and groundcover. Kandosols generally have low fertility and are highly susceptible to erosion and are mostly located in the upper Herbert River catchment where there are extensive areas of dryland grazing. Ferrosols are the ‘red soils’ of the Tablelands with exceptional physical properties that make them prized for agriculture, particularly sugarcane, dairying and horticulture. Ferrosols can be prone to surface water erosion if left bare as they are often very friable. Rudosols and tenosols soils occur in the upper Herbert basin on many types of parent material, with quartz-rich sandstones and siliceous volcanic rock the most common and are used mainly for grazing. These soils are highly erodible.

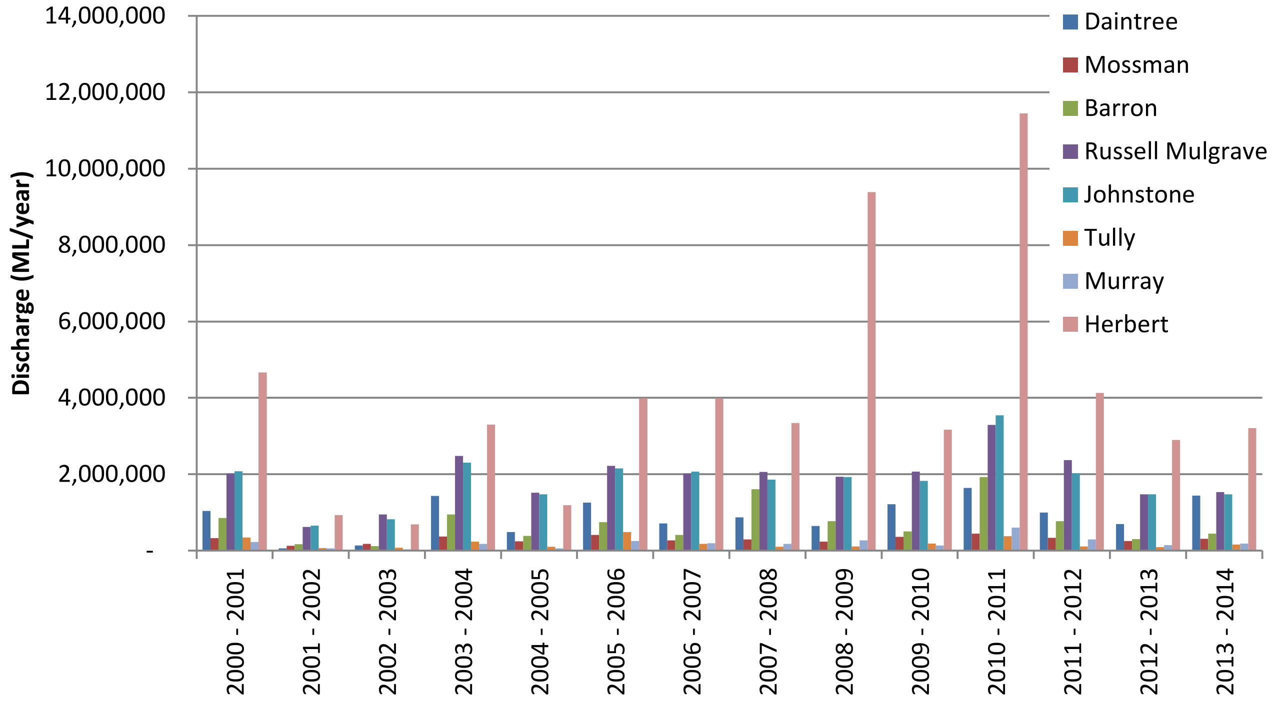


Figure 2.3. Annual discharge (ML/yr) for Wet Tropics basins (2000-2014). Source: Data supplied by DNRM, 2014; compiled by E. da Silva, TropWATER.

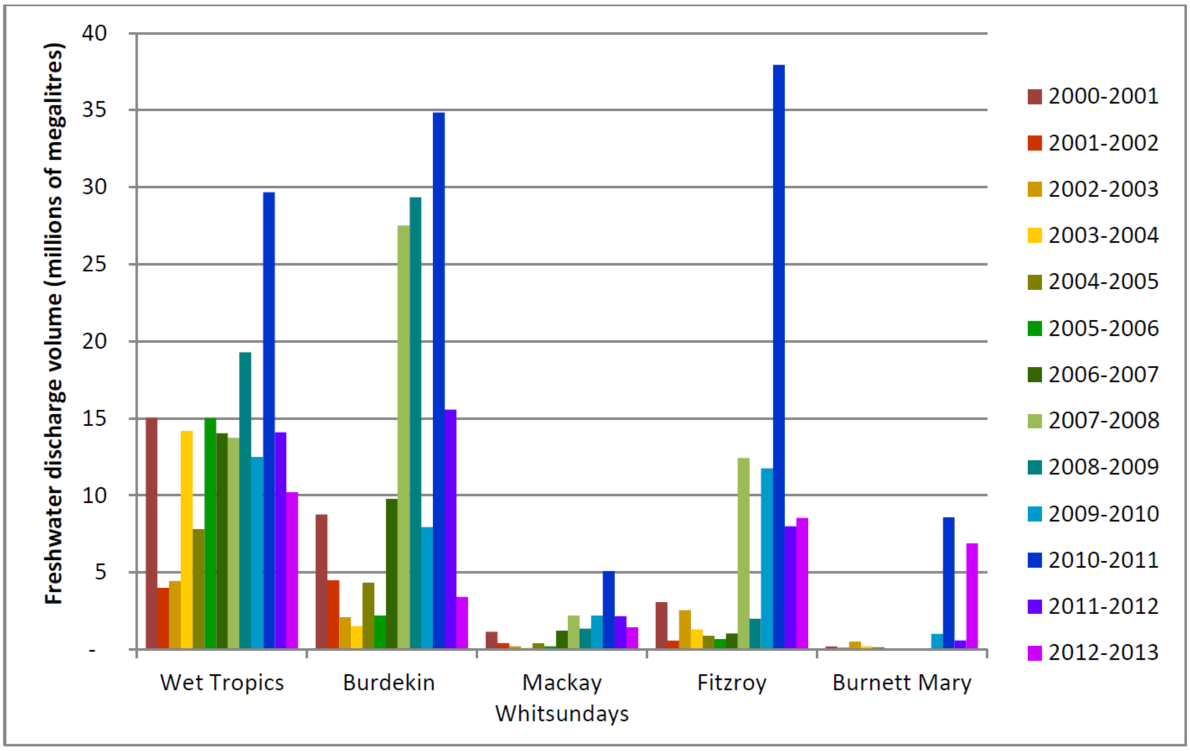


Figure 2.4. Combined annual discharge from major rivers in each region of the GBR, 2000-2013. Source: Data supplied by DNRM, compiled by AIMS.

2.2.3 Land use

Over the 160 years of European settlement, the GBR catchment has been highly modified from its natural state. Agricultural land use has become more widespread and more intensive. Historically, broadscale land clearing and intensive cropping on the coastal floodplain have affected coastal habitats and the processes that support the GBR environment (GBRMPA, 2014a). These changes are evident in the Wet Tropics, with intensive development of the coastal landscape in many locations.

The Wet Tropics supports a diversity of land uses as shown in Figure 2.5 and summarised in Figure 2.6. The dominant land uses in the region by area are nature conservation and forestry (approximately 11,000 km^2 or 51% of the total area) which is generally restricted to the mountainous regions as a consequence of extensive floodplain areas having been cleared since European settlement. Grazing also covers a relatively large area of the region (33% of total area) and is the major land use in the drier western part of the region, but is only a minor use of the coastal lowlands. Intensive agricultural industries including sugar cane, horticulture, bananas and cropping occupy around 10% of total area (DSITIA 2012a). The main crops of sugar cane (8% of the total area) and bananas are located predominantly in the coastal areas.

At the GBR scale, the Wet Tropics region accounts for 33% of the total sugar cane area in the GBR catchment, followed by the Mackay-Whitsunday area with 31%, and the Burdekin with 20%. The Wet Tropics contains 32% of the GBR catchment's horticulture (including bananas) (the Burnett Mary region has 39%). Grazing and cropping (not sugar cane) in the Wet Tropics only accounts for 2% and 1% respectively of the total GBR catchment area.

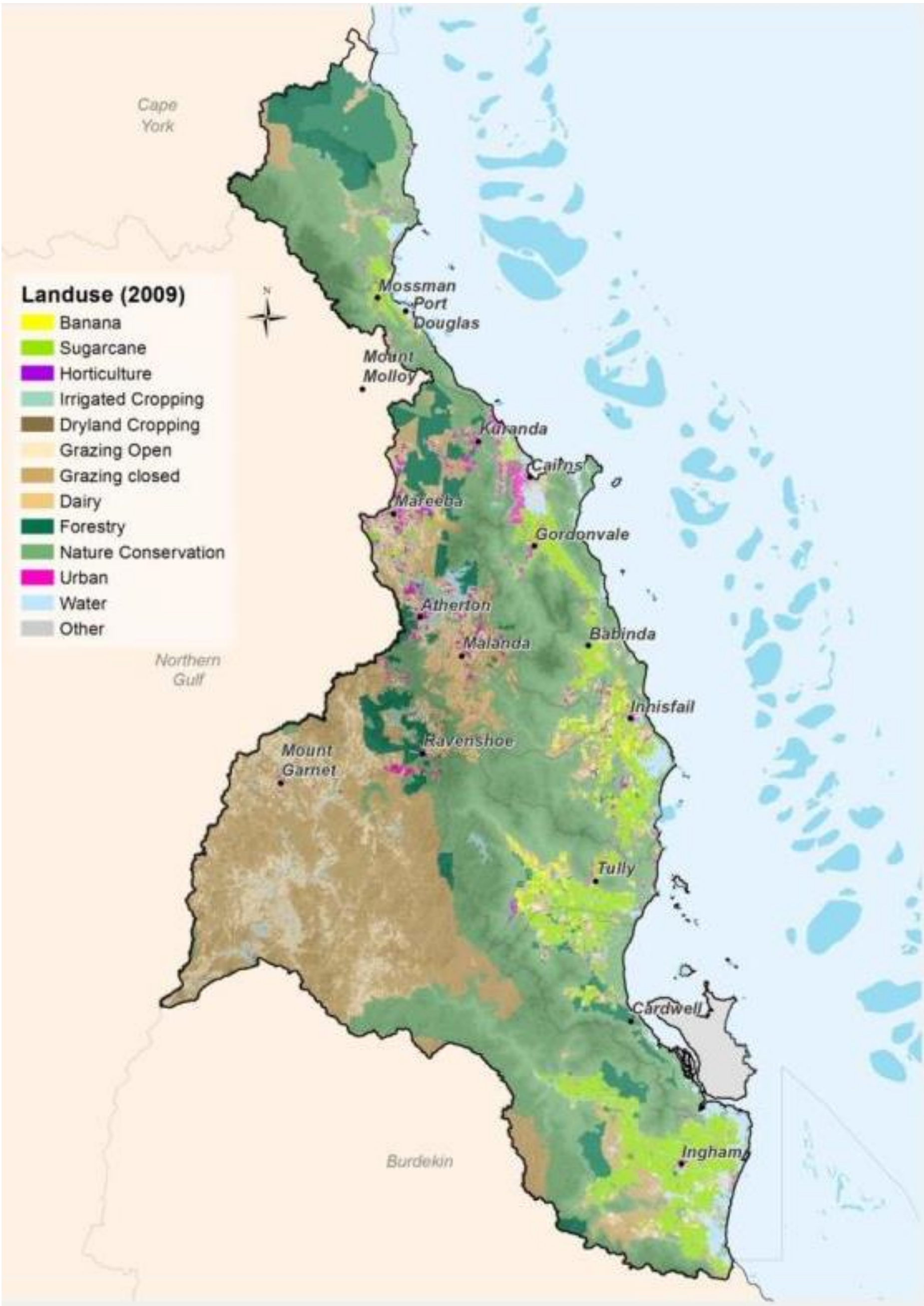


Figure 2.5. Land use in the Wet Tropics NRM region. Source: Data supplied by DNRM, QLUMP 2009.

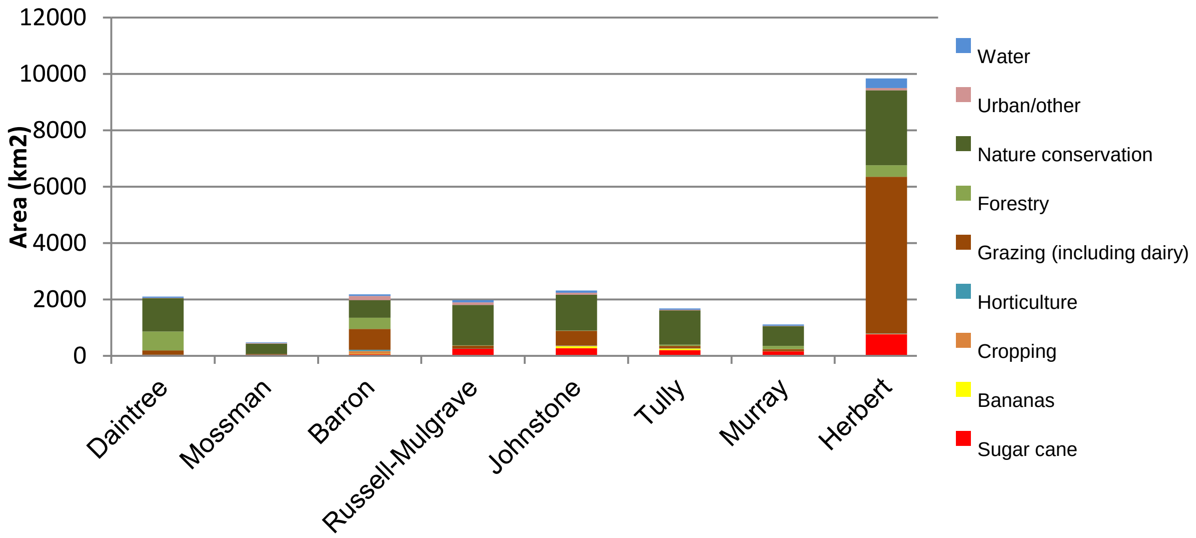


Figure 2.6. Estimated land use by area (km^2) in the Wet Tropics region (based on QLUMP data used in Source Catchments) (derived from Hateley et al. 2014).

The largest area of sugar cane is in the Herbert basin (759 km^2; 42% of the regional sugar cane area), followed by the Johnstone (16%), Russell-Mulgrave (14%), Tully (11%) and Murray (9%) basins. The area of sugar cane in the Daintree, Mossman and Barron basins is <5% of the regional area. The majority of the grazing land is in the Herbert basin (5,561 km^2; 77% of the regional area of grazing). The Barron and Johnstone basins also include ~10% of the regional grazing area (including dairy). The remaining basins only have small areas of grazing (<2%). The Barron basin also contains the largest area of crops other than sugar cane (109km^2; 77% of the regional area of cropping), with limited areas in all other basins except for some cropping in the Herbert basin (22%), mostly on the Evelyn Tableland. Bananas are mainly grown in the Johnstone and Tully basins (66 km^2 and 60 km^2 respectively; ~40% each), with ~10% of the regional area of bananas in the Barron basin.

The largest urban areas are in the Barron (145 km^2) and Russell-Mulgrave (90 km^2) basins. Urban population growth in the Wet Tropics is placing increasing pressure upon the region's good quality agricultural land (DAFF, 2014). Impacts of concern arising from land use change for residential and other urban purposes include loss of land and viability of agriculture in the Cairns region, and urban encroachment associated with tourism development along the Wet Tropics coast north of the Daintree, Cairns Northern Beaches, Mission Beach and Cardwell. Of major importance is the associated increasing demand for water supply which is a growing issue in the Cairns urban area and surrounds with particular pressure to source water from the adjacent Russell and Mulgrave basins. The Wet Tropics Water Resource Plan[9] will address some of the pressures associated with increasing water demand. Cairns Regional Council is also developing a Water Demand Strategy to address water supply which builds on the Far North Queensland Regional Water Supply Strategy[10].

Port and vessel facilities are located in Cairns (Port of Cairns), Mourilyan Harbour and Lucinda, and several marinas are located throughout the region near the urban settlements of Port Douglas, Yorkeys Knob, Cairns and Cardwell. The major facilities are based in Cairns. The Port of Cairns is a multi-purpose regional port that caters for a diverse range of customers from bulk and general cargo, cruise shipping, fishing fleet, defence vessels and reef day-trip passenger ferries. The Port's bulk cargo includes petroleum products, sugar, molasses, fertiliser and liquid petroleum gas (Ports North, 2014). The Port has long been the natural consolidation and redistribution centre for supplies that are shipped to the coastal communities north of Cairns as well as the Torres Strait Islands and the Gulf of Carpentaria. The Port is a supply and service centre for the Freeport mine operations in Indonesia with regular mine servicing shipping operations out of the Port, is one of the country's busiest cruising destinations with both major international cruise ships and a number of domestic cruise vessels operating out of Cairns, and also supports one of Australia's largest fishing fleets (Ports North, 2014). The Cairns Marlin Marina is a 261 berth marina accommodating a variety of cruising vessels, superyachts and reef vessel operations servicing the GBR. The Reef Fleet Terminal provides access to the Reef for more than 750,000 passengers each year (Ports North, 2014).

[9] http://www.dnrm.qld.gov.au/water/catchments-planning/catchments/wet-tropics
[10] http://www.dews.qld.gov.au/water-supply-regulations/regional-water-supply/far-north

2.3 Status, trends and threats of the Wet Tropics waterways and receiving waters

As described in Section 1, it is well established that the Wet Tropics NRM region is a high value area in terms of terrestrial, freshwater, coastal and marine assets and is being negatively impacted by declining water quality. The primary causes of declining water quality are direct inputs from land uses, and modification of the landscape and landscape functions that have the potential to reduce the amount of land based pollutants delivered to the receiving waters of the GBR.

2.3.1 Catchment waterways

The HWMP process undertaken in the Wet Tropics region in 2010 to 2012 provided a strong basis for assessing the environmental values of the region, and commenced a process of documenting current condition of the catchment waterways. This has been expanded through the assessment of freshwater ecosystems undertaken by Kroon et al. (2014) and Godfrey and Pearson (2012) and the information contained in local catchment management plans. Around 35% of the region is within the Wet Tropics WHA, which has provided a degree of protection to the integrity of the catchment waterways. However, a high proportion of freshwater ecosystems in the coastal areas and within developed land uses such as agriculture and urban areas are assessed to be in a moderately or highly disturbed state. This impact is particularly evident in the central basins of the region, essentially between Cairns and Ingham.

Key threats are associated with altered hydrology, loss of connectivity, loss and disturbance of habitat, decline in water quality and soil chemistry, introduction of pest species and extraction such as fishing. The interaction of multiple processes and the overarching influence of climate change also pose considerable threat to the Wet Tropics waterways. Some of these threats, such as fishing, are managed through legislative mechanisms while others, such as those associated with disturbance of habitat, can be addressed through local government and non-statutory regional planning processes.

2.3.2 Coastal and marine ecosystems

A detailed overview of the status of the Wet Tropics coastal and marine ecosystems is provided in Johnson (2014). Marine and coastal assets in the Wet Tropics region include diverse habitats – coral reefs, seagrass meadows, estuaries, coastal wetlands and islands – and the species they support. Many of these species are of conservation concern including dugong, humpback whale, six species of marine turtle, two species of seabird, and beach stone curlew. Other species that are considered rare in the GBR, such as the Irrawaddy and Indo-Pacific humpback dolphins, are found in the region and utilise critical marine habitats. These marine and coastal assets have ecological, social and cultural importance, and support important industries – tourism and fisheries – dependent on healthy ecosystems (Johnson, 2014).

The Wet Tropics region contains around 510km of coastline that includes coastal wetlands (tidal and ephemeral freshwater), estuaries and numerous coastal islands and cays. Notable among these is Hinchinbrook Island that has more than 20,000 hectares of mangrove wetland and estuary, with an island area of 39,900 hectares that is protected as a National Park[11]. These coastal assets support a tourism industry for recreational boating and hiking, recreational fisheries and aquaculture ventures for prawn, barramundi and crayfish[12].

Assessment of the current status of key marine and coastal assets in the Wet Tropics region has identified a number of assets that are in poor or very poor condition. These include: inshore coral reefs, inshore and reef seagrass meadows, dugong, low-lying islands, and species of climate sensitive seabirds.

Key drivers of change include cyclones and storms, COTS outbreaks, poor water quality, climate extremes, coastal development including ports and shipping, and the cumulative impacts of these pressures. Of critical importance, the Wet Tropics region has been identified as the area where primary crown-of-thorns starfish (COTS) outbreaks have most frequently been observed (see Furnas et al., 2013; Brinkman et al., 2014). COTS outbreaks are an important cause of coral loss on the midshelf and outer reefs of the GBR (De'ath et al., 2012) and based on current understanding, are a response to excess nutrient runoff from certain catchments that reaches this 'COTS initiation zone' (Fabricius et al., 2010). This area is assessed as the coral reefs between 14.5°S and 17°S (approximately between Lizard Island and Cairns) inside the GBR Marine Park boundary. The Wet Tropics rivers contribute more than 80% of the DIN loading to this initiation zone.

[11] http://nprsr.qld.gov.au/parks/hinchinbrook/about.html
[12] http://www.australiantropicalfoods.com/index.php/gourmet-foods/aquaculture/

The threats associated with poor water quality from land runoff are the focus of this WQIP, however, other influences are considered to be important, but not necessarily manageable, such as storms and cyclones. The potential influence of climate extremes in the future is discussed in Section 8 regarding the Wet Tropics in 2050. The impact of coastal development is discussed below, and addressed in other sections related to urban management and coastal ecosystems.

Ongoing and future coastal developments represent a potentially growing pressure on Wet Tropics marine and coastal assets, as does increasing shipping traffic and associated port infrastructure. The nature, location and extent of coastal development along the coast can directly remove or damage coastal wetlands and inshore seagrasses, and exacerbate the impacts from water quality. Development along coastal areas subject to increasing exposure to extreme weather events poses risks to coastal and marine assets, and continued development will further increase this risk.

The Port of Cairns is a significant coastal facility in the region situated in Trinity Inlet, which is protected under several pieces of environmental legislation due to significant environmental values at both national and International levels. Maintenance dredging of the port has been occurring for 100 years with inevitable environmental impacts on marine and coastal assets. The port is proposing further development of infrastructure in the inshore marine environment to accommodate larger cruise ships. Specifically, expansion of the existing shipping channel and shipping channel swing basin, expansion of the existing dredge material placement area, establishment of a new swing basin to support future expansion of the Cairns Navy base, and structural upgrade of the existing shipping wharves. These proposed developments will have implications for the marine and coastal assets of the region, particularly through the direct loss of inshore habitats, such as seagrasses, sediment and pollutant inputs to the marine environment, increased turbidity, and increased vessel traffic.

Dredging and dredge soil dumping produce high levels of turbidity (suspended sediments) in localised areas that may be dispersed up to 15–20 km from the dredging or dumping site depending on hydrology and weather conditions. Acute and chronic sediment exposure may lead to species loss, poor coral recruitment, increases in coral disease prevalence and a phase shift from corals to macroalgal communities (Erftemeijer and Lewis, 2006; Erftemeijer et al., 2012; Grech et al., 2013). Resuspension of heavy metals and other pollutants often occurs during dredging and dumping activities impacting adjacent benthic communities (Erftemeijerand Lewis, 2006; Kutser et al., 2007; Spearman et al., 2007).

There are approximately 2,273 lacustrine/ palustrine wetlands in the region, covering an area of 136,200 hectares (or 6% of the total regional area). Studies documenting changes to wetland habitats in the region identify a significant loss of 70% since pre-European development of the catchment (Queensland Wetlands Program, 2014). A major loss of mangrove and saltpan communities occurred in the Barron catchment due to the construction of the Cairns International Airport in 1982 (Bruinsma, 2001). Other losses are likely due to direct drainage and clearing, a decrease in freshwater runoff as a result of agricultural drainage, and changes in tidal flushing patterns caused by dredging (Bruinsma, 2001). Losses of wetland extent continue in the region, with an estimated areal loss of 1.2% between 2001 and 2009.

The threats identified in Table 2.1 indicate that declines are likely to continue for some marine and coastal assets due to the cumulative pressures of poor water quality, COTS outbreaks, climate change and development. It is for this reason that addressing chronic stressors caused by human activities, like degraded water quality, are important for maintaining and improving ecosystem condition. Improving water quality can decrease the sensitivity of corals and seagrasses to episodic disturbances when they occur, and improve recovery post-disturbance (e.g. Wiedenmann et al., 2013, Thompson et al., 2013). The events of recent years have shown that disturbances can occur every year in some locations for consecutive years, and that multiple events can even occur during the same year. As the return period between disturbances decreases, recovery will depend on maintaining ecological resilience and minimising chronic pressures such as poor water quality.

Table 2.1. Assessment matrix summarising the value of coastal and marine assets in the Wet Tropics region, their current status, trends of change, and future pressures and threats. This assessment is based on the best currently available information and in cases where information is limited, relies on expert judgment. Pressures in blue are those that cannot be managed by the WQIP. Source: Johnson (2014).

Asset	Value/service	Status*	Trends	Pressures/threats
Inshore coral reefs	Tourism, critical habitat, coastal protection & stabilisation	Barron-Daintree sub region– poor; Johnstone Russell-Mulgrave sub region – moderate; Herbert-Tully sub region – poor	Declining condition	Elevated nutrients and pesticides, turbidity, freshwater inputs, COTS, coastal development, extreme weather (i.e. tropical cyclones, floods), increasing SST (coral bleaching), ocean acidification
Midshelf & offshore coral reefs	Reef tourism, critical habitat, coastal protection	Moderate	Recent declines due to TC Yasi & COTS outbreak	COTS, extreme weather (i.e. tropical cyclones), increasing SST (coral bleaching), ocean acidification
Inshore seagrass meadows	Critical habitat (esp. dugong), coastal stabilization, nutrient cycling	Very poor (for all sub-regions)	Declining condition	Elevated nutrients and pesticides, turbidity, freshwater inputs, coastal development, extreme weather (i.e. tropical cyclones, floods), increasing SST
Midshelf & offshore (reef) seagrasses	Critical habitat, nutrient cycling, part of reef matrix	Poor (for all sub-regions)	Recent declines due to TC Yasi	Extreme weather (i.e. tropical cyclones)
Coastal wetlands	Critical habitat, coastal protection & stabilization, nutrient cycling, aquatic ecosystem protection	Moderate	Declining condition	Elevated nutrients and pesticides, coastal development, extreme weather (i.e. tropical cyclones, floods), sea-level rise
Island environments	Tourism income, critical habitat (esp. for seabirds & turtle nesting)	Moderate (Poor for some low-lying cays)	Recent declines due to TC Yasi and rainfall changes impacting vegetation	Human disturbance, introduced pests, extreme weather (i.e. tropical cyclones), sea-level rise, changing rainfall patterns
Dugong	Tourism income, cultural importance, ecosystem role	Poor to very poor	Recent declines due to TC Yasi & loss of seagrass	Declining seagrass condition, human disturbance/interactions, vessel strikes
Marine turtles	Tourism income, cultural importance, ecosystem role	Moderate (Poor for some species that nest on low-lying cays)	Stable	Human disturbance/interactions, declining nesting island condition, increasing air/sand temperatures
Fish/sharks	Commercial and recreational fisheries, herbivore role in reducing	Species dependent	Species dependent	Declining habitat condition, unsustainable fishing practices, increasing SST

Asset	Value/service	Status*	Trends	Pressures/threats
	macroalgae, apex predators			
Cetaceans	Tourism income, iconic megafauna, apex predators	Species dependent (consider conservation status)	Stable	Human disturbance/interactions, reduced prey availability, declining habitat condition
Seabirds	Tourism income, iconic fauna, apex predators	Species dependent (consider conservation status)	Stable or some species in decline (e.g. common noddy)	Human disturbance/interactions, reduced prey availability, declining habitat condition

** Status assessment is based on the Reef Plan Report Card five-point scoring system.*

Chapter 3: Strategy 1 - Reducing pollutant runoff from the Wet Tropics basins

3. Pollutant sources, management priorities and options in the Wet Tropics region

The amount of sediments, nutrients and pesticides that are delivered to the receiving waters of the GBR is influenced by several characteristics including rainfall, slope, soil type and land use which are described in Section 2.2. This section summarises the basis for the identification of priorities for management in the Wet Tropics region.

3.1 Key pollutants and sources

The largest sources of pollutants to the GBR are from agricultural land uses (Waters et al., 2014), however, other sources include point sources such as intensive animal production, manufacturing and industry, mining, rural and urban residential, transport and communication, waste treatment and disposal, ports/marine harbour, and shipping. Compared to diffuse sources, most contributions of such point sources are relatively small but could be locally and over short time periods highly significant. Point sources are associated with regulated activities (termed 'environmentally relevant activities' or ERAs) that have strict regulations regarding their waste outputs, particularly water quality.

Losses of different types of pollutants are typically associated with different land uses in the GBR catchments (Kroon et al., 2013). For example, a strong relationship exists between the areas of nitrogen-fertilised land use in a catchment and the average dissolved inorganic nitrogen (DIN) concentration during high flow conditions, implicating fertiliser residues as the source of DIN. Elevated stream concentrations of DIN indicate fertiliser application above plant requirements in sugar cane and bananas; concentrations of nitrate are also elevated in groundwater in many areas under intensive agriculture. Analysis of data on fertiliser use, loss potential and transport has ranked fertilised agricultural areas of the coastal Wet Tropics among the hot-spot areas for nutrients (mainly nitrogen) that pose the greatest risk to the GBR. In the Wet Tropics, sediment fluxes are comparatively lower due to high vegetation cover maintained throughout the year from high and year- round rainfall and different land management practices from those in the dry tropics regions within industries such as beef grazing. Urban development sites can be local high impact sources of suspended sediment. Concentrations of pesticides in waterways are highest in areas of intensive agricultural activity including sugar cane. Of the herbicide residues most commonly found in surface waters in the GBR region, diuron, atrazine, ametryn, hexazinone derive largely from areas of sugar cane cultivation, while tebuthiuron is derived from rangeland beef grazing areas. Herbicide residues are present in groundwater at many locations.

The distribution of land uses in the region therefore has an important influence on regional priorities for water quality management.

The results from the Source Catchments model of end-of-catchment pollutant loads for the Wet Tropics region have been used to describe pollutant loads by land use and basin so that management priorities can be determined within the region. The three different types of loads presented here include the total baseline and anthropogenic baseline loads (total baseline – predevelopment) (based on management data as at July 2008) and Report Card 2013 loads (representing management as at July 2013). All loads are generated from the same static climate period (1986-2009) and the same land use (2009).

To provide the regional context, a summary of land use and pre-European, baseline and Report Card 2013 loads of total suspended sediment (TSS), dissolved inorganic nitrogen (DIN) and phosphorus (DIP), particulate nitrogen (PN) and phosphorus (PP) and photosystem II inhibiting (PSII) herbicides in the Wet Tropics are provided in Appendix 3 (sourced from Hateley et al., 2014). A comparison of these loads against the target loads for each basin and progress towards the Reef Plan targets is also provided (derived from Hateley et al., 2014 and Brodie et al., 2014).

The results indicate that a large proportion of the total load is derived from anthropogenic changes, with the following proportions of anthropogenically derived loads: TSS 60%, DIN 42%, DIP 2%, PSII 100%, PN 49%, PP 17%.

The 2013 Report Card Source Catchment modelled end-of-catchment baseline (2008) pollutant load estimates[13] for the Wet Tropics region are derived from Hateley et al., (2014). Within the Wet Tropics region, the Johnstone and Herbert basins were the highest overall contributors for all constituents. A summary of each of the key pollutants by basin and land use contributions is provided below.

TSS: The Herbert basin contributed the greatest proportion (38%) of the total regional TSS load. Compared to other basins in the region, the Herbert basin contributes at least twice as much of the anthropogenic load; the next greatest contribution is from the Johnstone basin, and the others contribute less than 10% of the anthropogenic proportion of the total load. The lowest contribution is from the Daintree-Mossman basin (~2%). In comparison to all other GBR basins, the Hebert basin is the third largest contributor of TSS to the total GBR TSS load, however, the Wet Tropics region only contributes 14% of the total GBR TSS load.

Grazing was the biggest source of TSS when compared to the other land uses at 247 kt/yr or 32% of the total export load. Sugar cane was the next biggest source and contributed approximately 29% of the TSS export load at 219 kt/yr. However, on a land use by area basis, bananas contributed the highest areal rate of TSS at 1.8 t/ha/yr, followed by sugar cane at 1.2 t/ha/yr then horticulture at 1.1 t/ha/yr.

Urban land uses contribute TSS at ~0.85 t/ha/yr (ranked lower than all cropping land uses).

Nature conservation i.e. protected areas, usually on the very steep terrain, contributes 178 kt/yr or 23% of the total TSS export load. Streambank erosion is not a land use (nor attributable to any specific land use in the modelling structure), however this type of erosion accounted for 452 kt/yr of the total export TSS load, which is almost double that of grazing and shows that some of these loads are naturally occurring.

There are around 800 wet grazing properties (including 59 dairy properties) in the Wet Tropics, particularly in the Tablelands. Wet grazing has high ground cover, and in the case of beef may only apply limited N to pastures every 3-5 years, however fertiliser is typically applied annually in dairy. High ground cover means there is also limited sediment loss.

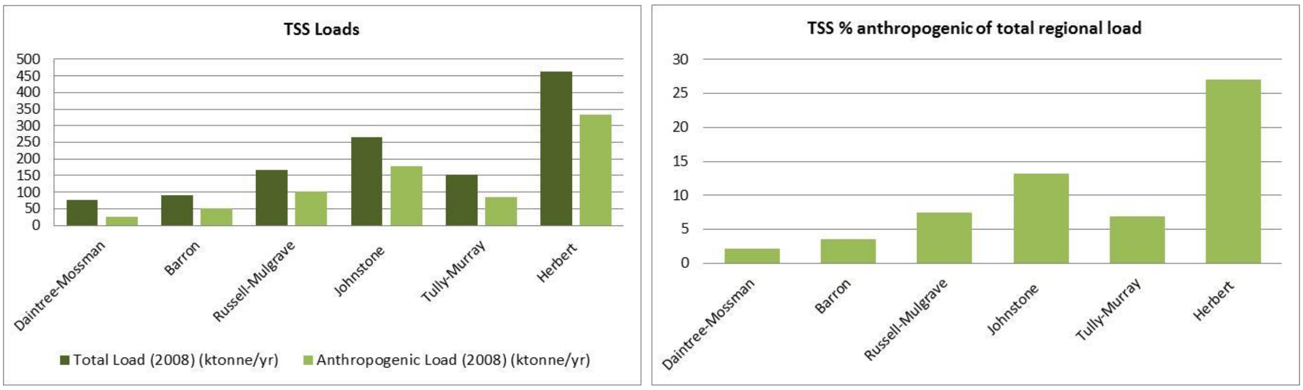


Figure 3.1. Annual load estimates for TSS from the basins in the Wet Tropics region. The graphs show (a) Total (2008) and anthropogenic loads (2008) (kilotonnes), and (b) the proportion that the anthropogenic TSS from each basin contributes to the regional Total TSS Load.

DIN: The Johnstone basin contributes the highest total DIN load and anthropogenic DIN load followed by the Tully-Murray basin. The anthropogenic contribution from the Johnstone accounts for ~19% of the total regional load. The Tully-Murray (11%) basin contributes around 10% of the anthropogenic load to the regional total load and the other basins contribute 5% or less. In comparison to other NRM regions, the Wet Tropics region has the greatest total DIN load (42% of the GBR total).

[13] The estimates are based on the 2008 baseline estimates ran in 2013 for Report Card 4 and 5.

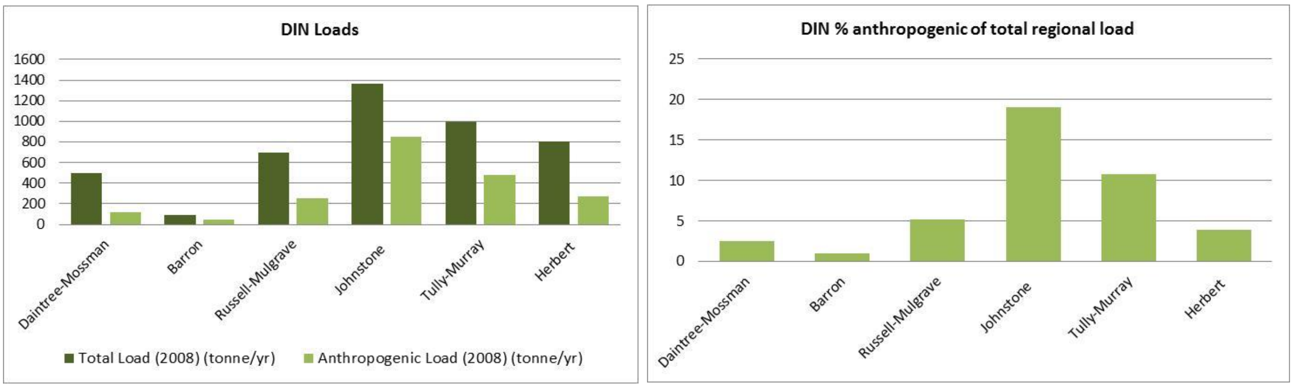


Figure 3.2. Annual load estimates for DIN from the basins in the Wet Tropics region. The graphs show (a) Total (12/13) and anthropogenic loads (12/13) (tonnes), and (b) the proportion that the anthropogenic DIN from each basin contributes to the regional Total DIN Load.

Sugar cane had the highest proportion of the DIN export load at 41% (1,828 t/yr) followed by nature conservation 1,411 t/yr or 32%, although this is a natural and not an anthropogenic source. Anthropogenic DIN load contributions across the region are shown in Figure 3.3. The greatest contributions are from sugar cane (74%), bananas (10%) and urban (8%) land uses.

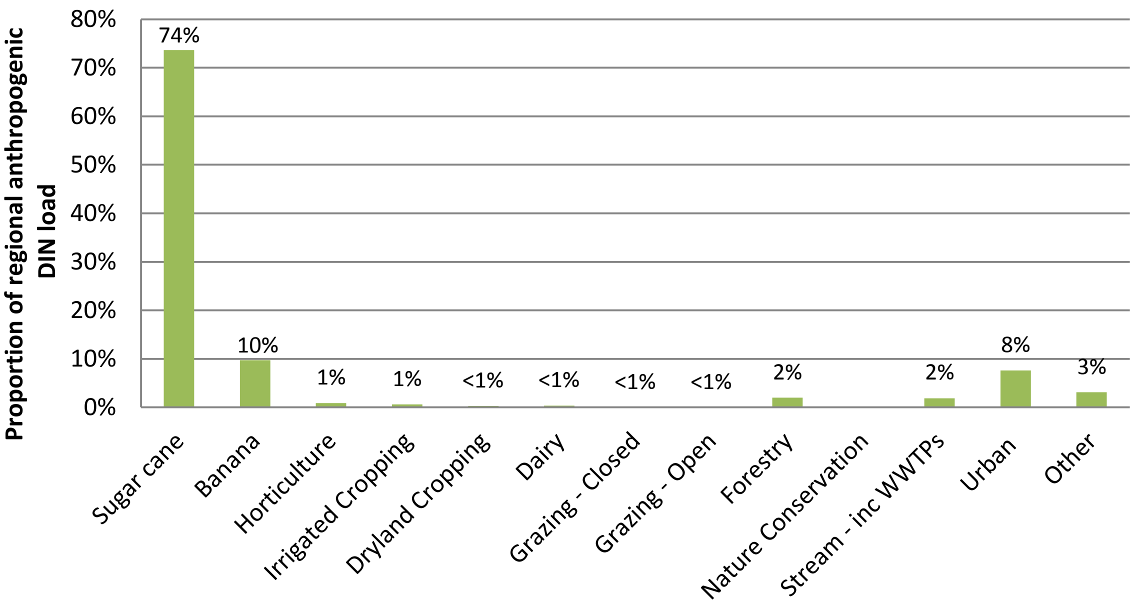


Figure 3.3. Land use contribution to anthropogenic DIN loads for the Wet Tropics region (2008 baseline data). Source: Hateley et al. (2014).

The anthropogenic DIN loads from each land use for each basin are shown in Figure 3.4, and as a proportion of the regional anthropogenic DIN load in Figure 3.5. Land use contributions vary between basins, with DIN loads from sugar cane in the Johnstone showing as a significant contributor to the regional anthropogenic DIN load. Source Catchments modelling estimates indicate that sugar cane contributes a large proportion of the DIN load in the Mossman (65%), Russell-Mulgrave (60%), Johnstone (80%), Tully (74%), Murray (81%) and Herbert (88%) basins.

Two ‘hotspot’ basins for DIN loads from bananas are the Johnstone and the Tully basins (limited banana farming occurs in the other basins).

DIN contributions from urban diffuse sources are greatest in the Mulgrave (Cairns urban area) and Johnstone basins. However, proportional contributions vary considerably between basins and these sources are important for some basins; for example, the largest contributor to DIN loads in the Barron basin is urban diffuse sources (24%) and WWTPs (32%). Approximately 20% of the anthropogenic DIN load in the Daintree and Mossman is from urban diffuse sources.

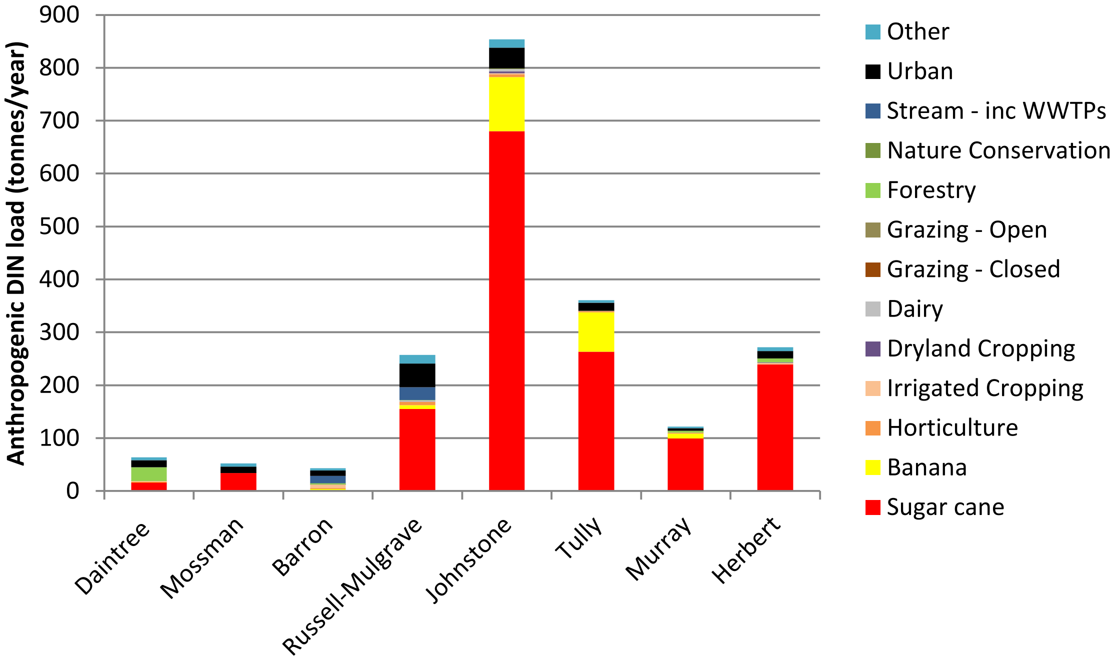


Figure 3.4. Land use contribution to anthropogenic DIN loads for each of the Wet Tropics basins (2013 baseline data). Source: Hateley et al. (2014).

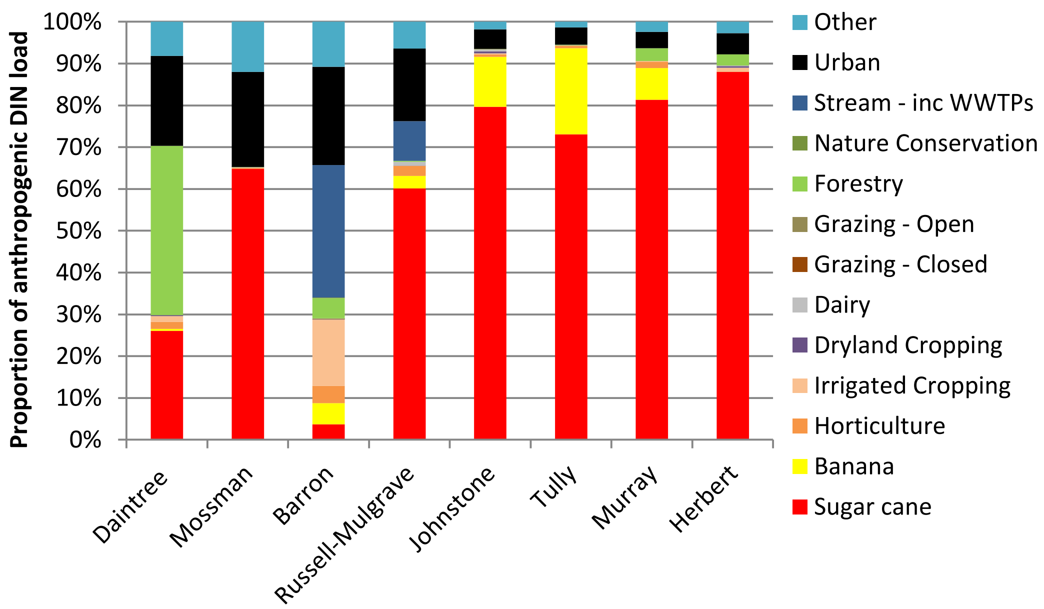


Figure 3.5. Land use contribution to anthropogenic DIN loads as a proportion of the regional anthropogenic baseline load for each of the Wet Tropics basins (2013 baseline data). Source: Hateley et al. (2014).

Land use contributions of pollutant export per unit area can assist in identifying pollutant generation hotspots. The modelling indicates that bananas generated the highest areal load for DIN at 15 kg/ha/yr, followed by sugar cane at 10 kg/ha/yr and urban/other at 6 kg/ha/yr. There are also considerable variations between basins (Figure 3.6).

The range of DIN for bananas was 2 kg/ha/yr in the Barron Basin to 24 kg/ha/yr in the Russell-Mulgrave Basin. For sugar cane, the range was 1 kg/ha/yr in the Barron to 27 kg/ha/yr in the Johnstone Basin. For cropping, the range was from 1 kg/ha/yr in the Barron and Herbert basins to 13 kg/ha/yr in the Daintree and Tully basins. For horticulture, the range was again from 1 kg/ha/yr in the Barron and Herbert basins to 9 kg/ha/yr in the Mulgrave-Russell basin.

Urban land uses contribute DIN at 6 kg/ha/yr (ranked third after bananas and sugar cane).

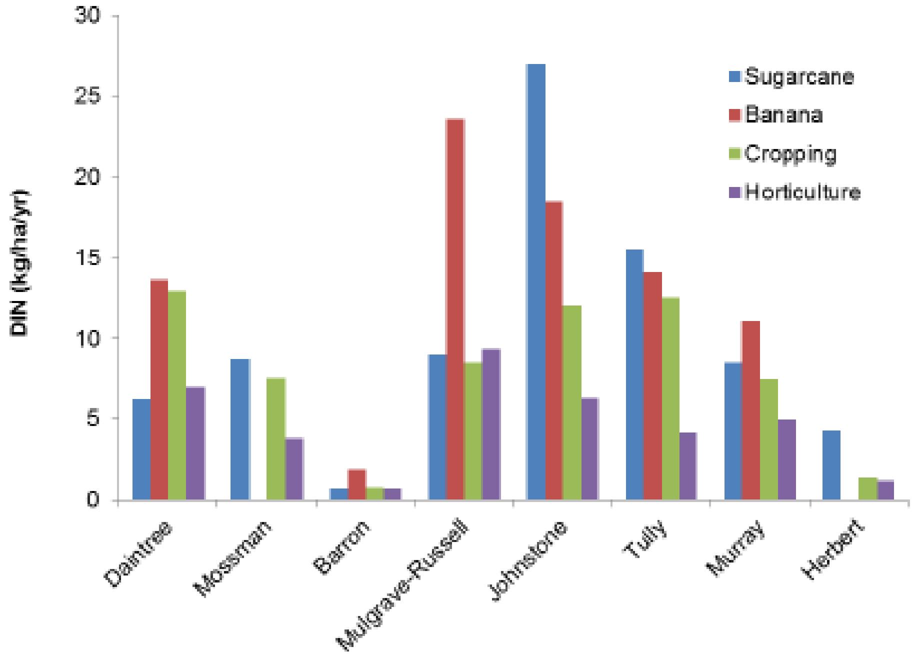


Figure 3.6. Modelled DIN (kg/ha/yr) export by basin for sugar cane, banana, cropping and horticulture land use in the Wet Tropics region (2013 baseline). Source: Hateley et al. (2014).

PSII herbicides: The Herbert basin contributes the greatest PSII herbicide load in the region (Figure 3.6), estimated at 1,850 kilograms per year (note that the total load is equal to the anthropogenic load because pesticides were not present before development intervention). This amount accounts for approximately 29% of the regional load. The Tully-Murray basin contributes 25% to the regional load, followed by the Johnstone (~20%) and Russell-Mulgrave (~18%) basins. The Barron and Daintree-Mossman basins contribute <5% of the regional load each. In comparison to other NRM regions, the Wet Tropics region has the greatest PSII herbicide load (51% of the GBR total). These contributions are positively correlated with the area of sugar cane land use in each basin or region.

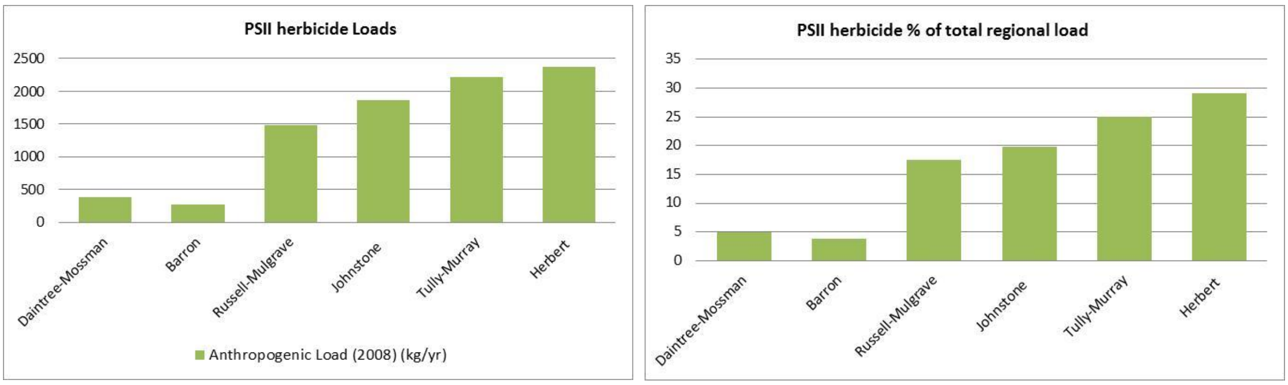


Figure 3.7. Annual load estimates for PSII herbicides from the basins in the Wet Tropics region. The graphs show (a) anthropogenic loads (12/13) (kg), and (b) the proportion that the anthropogenic PSII herbicides from each basin contributes to the regional Total PSII herbicides Load.

Sugar cane contributed the highest PSII herbicide export load, contributing 96% to the regional load with the remaining 4% from cropping (Figure 3.7). The contribution of sugar cane to PSII herbicide loads is >95% for all of the basins in the Wet Tropics except for the Barron which is 33% from sugar cane and 66% from other crops.

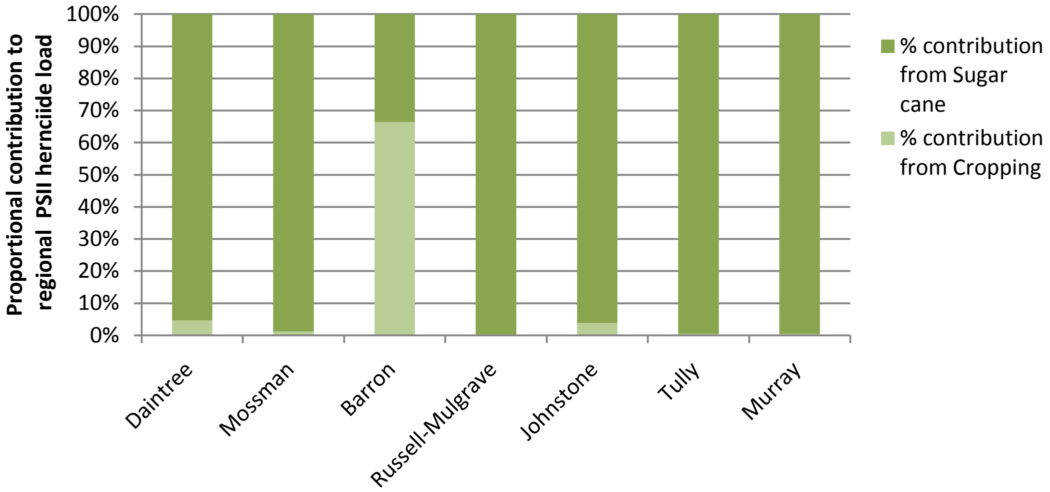


Figure 3.8. Land use contribution to PSII herbicide loads for each of the Wet Tropics Basins (2013 baseline data). Source: Hateley et al. (2014).

Across the region, sugar cane had the highest export areal rate of 46 g/ha/yr for PSII herbicides, followed by cropping at 23 g/ha/yr. There was a range of values for PSII herbicides for sugar cane by basin, from 16 g/ha/yr in the Barron Basin to 67g/ha/yr in the Tully Basin (Figure 3.9).

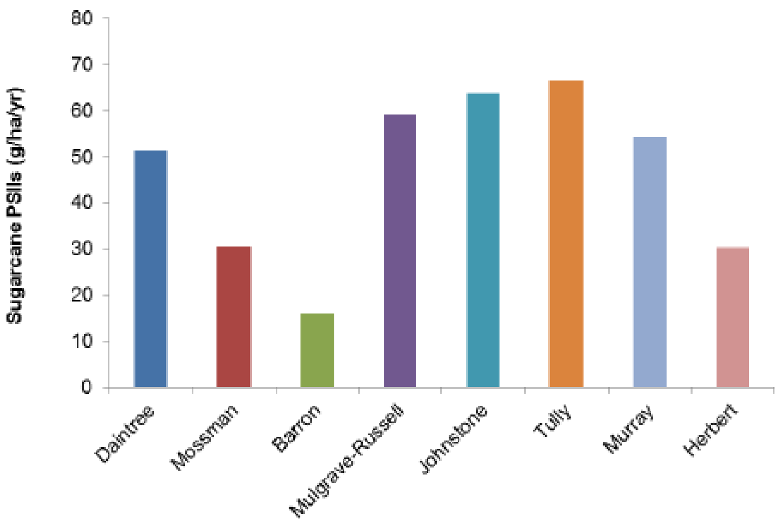


Figure 3.9. Modelled PSII herbicides (g/ha/yr) export by basin for sugar cane land use for each basin in the Wet Tropics region (2008 baseline). Source: Hateley et al. (2014).

PN: The Johnstone basin contributed 30% of the total PN load, followed by the Herbert at 27%. The Johnstone and Herbert basins contribute the greatest anthropogenic PN loads in the region. These anthropogenic contributions account for approximately 19% of the total regional load each. In comparison all other basins only contribute a small proportion to the regional anthropogenic load (<7%). In comparison to other NRM regions, the Wet Tropics region contributes 32% of the total GBR PN load.

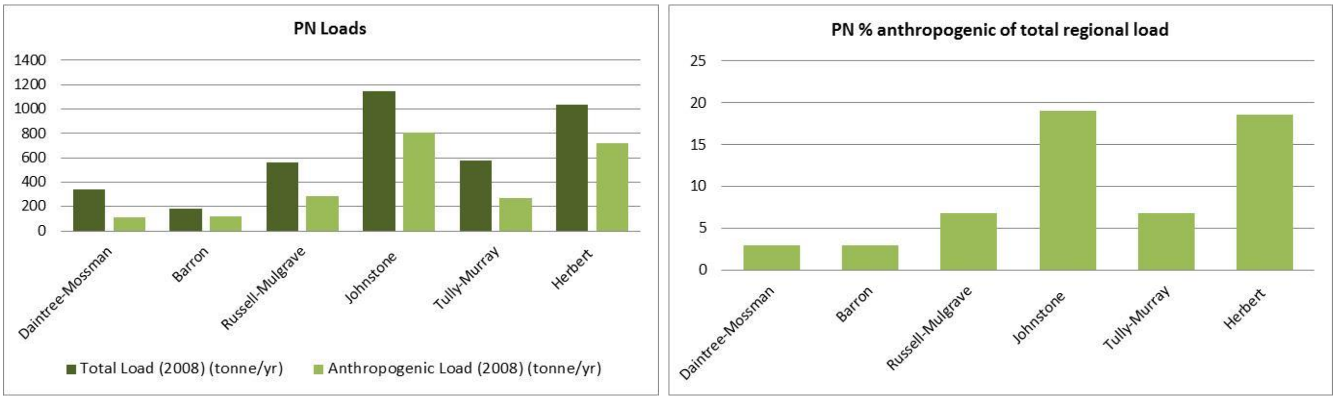


Figure 3.10. Annual load estimates for Particulate Nitrogen (PN) from the basins in the Wet Tropics region. The graphs show (a) Total (12/13) and anthropogenic loads (12/13) (tonnes), and (b) the proportion that the anthropogenic PN from each basin contributes to the regional Total PN Load.

DIP: Both the Johnstone and Herbert basins contributed similar amounts to the total DIP loads for the region, at approximately 21% each. The Johnstone and Tully-Murray basins contribute the greatest anthropogenic DIP loads in the region. These anthropogenic contributions each account for approximately 9% of the total regional load. The anthropogenic loads from the Russell Mulgrave and Herbert basins are also similar at around 15 tonnes. In comparison to other NRM regions, the Wet Tropics region contributes 20% of the total GBR DIP load.

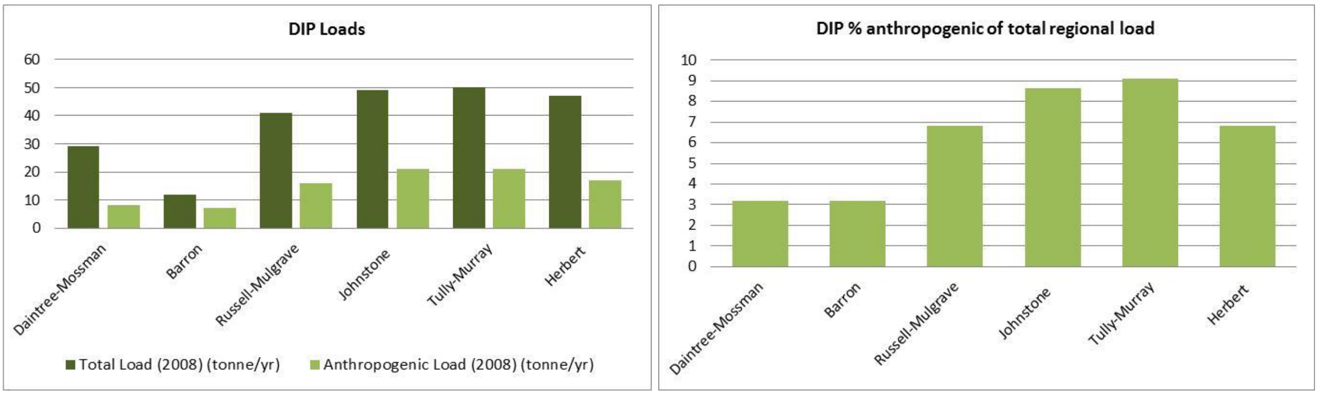


Figure 3.11. Annual load estimates for Dissolved Inorganic Phosphorus (DIP) from the basins in the Wet Tropics region. The graphs show (a) Total (12/13) and anthropogenic loads (12/13) (tonnes), and (b) the proportion that the anthropogenic DIP from each basin contributes to the regional Total DIP Load.

PP: The Johnstone basin contributed 35% of the total regional PP load. The Johnstone and Herbert basins contribute the greatest anthropogenic PP loads in the region. The anthropogenic contribution accounts for approximately 22% of the total regional load. All other basins contribute a small proportion to the regional anthropogenic load. In comparison to other NRM regions, the Wet Tropics region contributes 28% of the total GBR PP load.

Sugar cane had the highest export areal load for PP at 2.4 kg/ha/yr, followed by bananas at 1.5 kg/ha/yr.

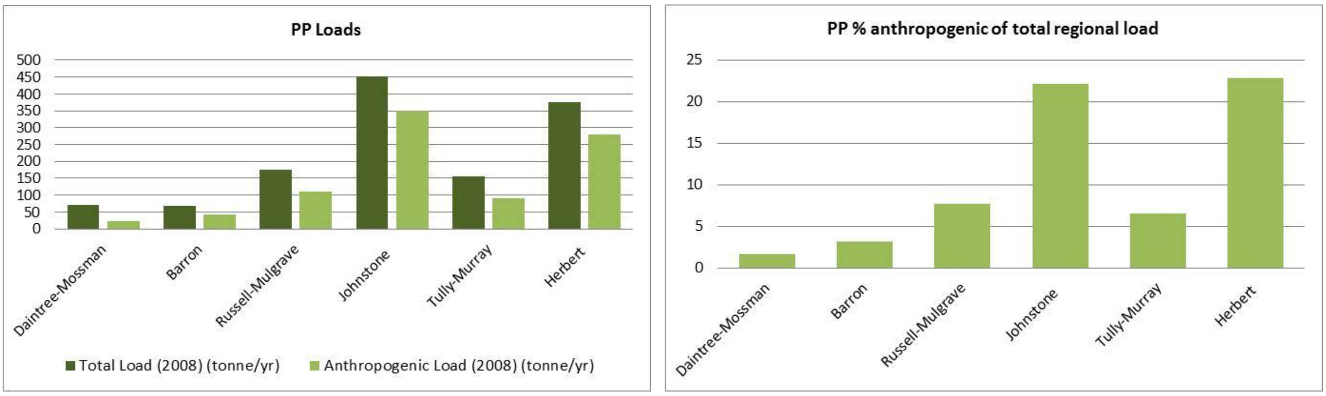


Figure 3.12. Annual load estimates for Particulate Phosphorus (PP) from the basins in the Wet Tropics region. The graphs show (a) Total (12/13) and anthropogenic loads (12/13) (tonnes), and (b) the proportion that the anthropogenic PP from each basin contributes to the regional Total PP Load.

Urban land uses contribute a large range of pollutants including TSS, nutrients, pesticides and other pollutants such as heavy metals, hydrocarbons and pharmaceuticals. Table 3.1 shows the annual estimates of pollutant loads from the main sewage treatment plants in the region, and Table 3.2 shows an assessment of all point sources. Overall, urban land uses contribute less than 7% of the total regional load for all constituents.

Table 3.1. Pollutant load estimates from major sewage treatment plants in the Wet Tropics region. Source: Hateley et al. (2014).

Name of sewage treatment plant	Discharge point	Basin	DIN (kg/yr)	DON (kg/yr)	DIP (kg/yr)	DOP (kg/yr)
Marlin Coast	Avondale Creek	Barron	5,011	1,332	970	274
Northern	Barron River		8,758	2,328	1,922	542
Southern	Smith's Creek (Trinity Inlet)	Mulgrave	22,104	5,876	3,520	993
Edmonton	Trinity Inlet		2,567	682	347	98

Table 3.2. Estimate of total point source pollutant contributions in the Wet Tropics region. Source: Hateley et al. (2014).

	TN (t/yr)	DIN (t/yr)	DON (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)
Point source estimate (all)	48	38	10	9	7	2

Emerging pollutants: A study was commissioned by Terrain to examine the sources and risk of 'emerging pollutants' in the Wet Tropics NRM region (O'Brien et al. 2014). Two specific sources and pollutants were examined: (1) pesticide residues from the mixed cropping land use in the Upper Barron River (i.e. above the Tinaroo Dam) and (2) pharmaceuticals, personal care products and pesticides from the Sewage Treatment Plants in the Cairns Region that discharge into Trinity Inlet.

A total of 14 pesticide residues, 3 herbicide degradation products, 2 synthetic musks and 1 flame retardant were detected in the passive samplers and grab samples in the Upper Barron River between December 2013 and March 2014. The sampling captured low flow (mid-December to mid-January), high flow (mid-January to mid-February) and moderate flow (mid-February to mid-March) events. The residues detected included the herbicides ametryn, atrazine, diuron, hexazinone, metolachlor, metsulfuron methyl, pendimethalin, picloram, prometryn, simazine and tebuthiuron and the herbicide degradation products, 3,4-dichloroanaline (diuron metabolite), desethyl atrazine and desisopropyl atrazine (atrazine metabolites). The insecticides detected included chlorpyrifos, diazinon and imidacloprid and the synthetic musks detected were galaxolide and tonalide. Tris (2-chloro-1-methylethyl) phosphate (TCIPP) was the only detected flame retardant in the samples. Our analysis suggests that none of these chemicals were detected at concentrations known to cause environmental harm, although diazinon and chlorpyrifos exceeded 99% ecological protection trigger values during each of the three monthly monitoring periods undertaken. However, the 95% trigger values were not exceeded and are more appropriate to apply given this would be considered a moderately disturbed site. Overall, compared to other regions of the GBR, the pesticides (and other chemicals) in the Upper Barron Catchment that drain into Tinaroo Dam, are considered low risk.

Passive and grab sampling at the Edmonton and Southern wastewater treatment plants (WWTP) that drain into Trinity Inlet was conducted from December 2013 to March 2014 to examine the concentrations of various pesticides, pharmaceuticals and personal care products (PPCPs) in both untreated influent and treated sewage effluent. The treatment processes undertaken likely remove the chemicals that have an affinity for particulate/organic matter and/or are prone to photodegradation. The results obtained show that several of the monitored chemicals were removed during the treatment process and few remained in the treated effluent that is discharged into Trinity Inlet (note that there are potentially hundreds to thousands of chemicals for which analysis is not undertaken because of the limitations in analytical capacity at this time). Chemicals detected at both WWTPs include the artificial sweetener acesulfame, pesticides and pharmaceuticals (including antibiotics, analgesics, anti-convulsants, antidepressants, diuretics, and medical dyes). None of these chemicals were detected at concentrations known to cause environmental harm (where there are toxicity data available and also considering dilution within Trinity Inlet). Hence the risk of pesticides, pharmaceuticals and personal care products discharged from sewage treatment plants in the Cairns region into Trinity Inlet is considered to be low. The results of the study indicated that these emerging pollutants currently pose a relatively low risk in the Wet Tropics region compared to the more recognised pollutants of suspended sediments nutrients and PSII herbicides. It is recommended that episodic monitoring be carried out (i.e. every few years) on these emerging pollutants to ensure their risk remains negligible. Indeed as analytical capacity and toxicity studies advances in the coming years, a more quantifiable risk profile can be established for these constituents.

3.2 Priority areas for reducing pollutant runoff

The relative risk of degraded water quality among the basins in the Wet Tropics region was determined by combining information on the estimated ecological risk of water quality to coral reefs and seagrass meadows in the region with end-of-catchment pollutant loads. The framework was based on that developed for the GBR wide relative risk assessment conducted by Brodie et al. (2013a) to inform Reef Plan 2013 priorities and modified where necessary to reflect issues and data availability in the Wet Tropics region. There are also several improvements to the input data compared to the GBR wide assessment. These include:

- Definition of zones of influence for each basin in an attempt to attribute marine risk back to individual basins.
- Refinement of the COTS influence modelling using four years of data rather than one (2010-11) to consider inter-annual differences. This has revealed differences in the main influences between high flow and low flow years.
- The contribution of DIN into the COTS Initiation Zone has been incorporated as opposed to just volumetric input. The annual DIN loads estimated by Lewis et al., (2014a) take into account the whole basin.
- Incorporation of additional pollutants in the assessment of end-of-catchment loads; this assessment includes TSS, DIN, PSII herbicides as well as PN, DIP and PP.

For assessment of the marine risk, a suite of water quality variables was chosen that represent the pollutants of greatest concern with regard to land-sourced pollutants and potential impacts on coral reef and seagrass ecosystems. These include exceedance of ecologically-relevant thresholds for concentrations of total suspended solids (TSS) and chlorophyll *a* obtained from daily remote sensing observations, and the distribution of key pollutants including TSS, dissolved inorganic nitrogen (DIN) and photosystem II-inhibiting herbicides (PSII herbicides) in the marine environment during flood conditions (based on end-of-catchment loads and plume loading estimates). A factor that represents the influence of Crown of Thorns Starfish (COTS) on coral reefs, and the differential influence of river discharges on the COTS initiation zone was also included. Modelled end-of-catchment pollutant loads (generated from the Source Catchments model framework for the Paddock to Reef Program) were obtained for each basin for key pollutants (TSS, DIN, PSII herbicides, PN, DIP and PP), and only the anthropogenic portions of regional total pollutant loads were considered in relating the relative risk to the basins. The anthropogenic load is calculated as the difference between the long term average annual load, and the estimated pre-European annual load.

The information was then considered by technical experts to make conclusions about the relative risk of degraded water quality to coral reefs and seagrass meadows among the basins in the Wet Tropics region. The marine assessment for each basin was constrained to the 'zones of influence' defined for the main rivers in the Wet Tropics region. These zones of influence for rivers were defined using outputs from the AIMS hydrodynamic model for the 2010-11 wet season (December to April inclusive). The rivers that are modelled in the region include the Daintree, Barron, Russell-Mulgrave, Johnstone, Tully and Herbert. The zones represent the areas of an average distribution of wet season river plumes (described in Waterhouse et al., 2014), however, the entire 'zone' is weighted equally and therefore does not factor in a water quality gradient of distance from the river mouth. This gradient is however represented in the actual water quality conditions that comprise the Marine Index described below.

The key results are summarised below (from Waterhouse et al., 2014).

Marine risk

When all water quality variables are combined into the Marine Risk Index, the risk is greatest for coral reefs in the Tully-Murray basins, and for seagrass in the Tully-Murray and Herbert basins. The areas in the Very High relative risk class were located in the coastal areas around Hinchinbrook Island, extending north to the Tully River mouth and south to the regional boundary at the southern part of the Herbert basin. This area is locally influenced by the Herbert, Murray and Tully Rivers, but also receives water from the large Burdekin River in the Burdekin NRM region. The high relative risk is associated with high exceedance of all water quality parameters in this location, except for the COTS Initiation Zone, and the presence of large areas of inshore coral reefs and seagrass in these high risk areas. While the areas of coral reef and seagrass within the highest assessment classes for individual variables and the Marine Risk Index are relatively small, they often include highly valued tourism and recreation sites of the GBR. Examples include Hinchinbrook Island, Goold Island, the Brooks Islands, and the Family Island group including Bedarra Island and Dunk Island. In the case of seagrass meadows, many of the highest risk areas overlap with dugong protection areas around Hinchinbrook and Taylors Beach, which are assigned because of the large populations of dugongs feeding in the associated seagrass meadows.

This combined assessment of water quality variables can be used to guide overall management priorities for addressing the risks from degraded water quality to coral reefs and seagrass between Wet Tropics basins. It is noted that there are some uncertainties in the input data associated with limitations to the remote sensing data and plume loading analysis in the region described in Waterhouse et al. (2014). However, it is not expected that the relative differences between the results would vary considerably to change the overall rankings of relative risk.

End of catchment loads

An assessment of end of catchment loads provides a link between the marine risk and land based pollutant delivery. The anthropogenic load was incorporated as a proportion of the total regional load, as it is only the anthropogenic portion that is assumed to be the 'manageable' component of pollutant loads. In the assessment of end-of-catchment pollutant loads the greatest relative contributions of combined end of basin loads to the Wet Tropics region is from the Herbert and Johnstone basins. The anchored score indicates that the contribution from the Tully Murray basin is approximately 60% of that from the Herbert and Johnstone basins, and the contribution from the Russell-Mulgrave basin is approximately 47% of that of the Herbert and Johnstone basins. The Barron and Daintree are relatively low contributors to regional pollutant loads compared to the other basins (approximately 16% of that contributed by the Herbert and Johnstone basins).

COTS Influence

The influence of river discharges on the COTS primary outbreak area was assessed by modelling the volumetric contributions and predicted DIN delivery into the 'COTS Initiation Zone' between Lizard Island and Cairns. The Burdekin has a significant influence on this area during high flow years such as 2010-11. When considering only the Wet Tropics rivers (i.e. Daintree, Barron, Russell-Mulgrave, Johnstone, Tully and Herbert Rivers) the Johnstone is estimated to present the largest risk of contributing to the DIN pool in the COTS Initiation Zone. The high level of DIN risk from the Johnstone River is related to the large volume discharged (mean = 3.2 km^3 over the 4 years of simulation) but also due to the high estimated event mean concentration of DIN in the discharge (321 µg N L^{-1}).

The Russell-Mulgrave and Tully Rivers rank consecutively lower than the Johnstone River for DIN risk, however the mean risk values for these three rivers are similar. When comparing discharges and volumetric contributions to the outbreak region from these three Rivers, the Russell-Mulgrave consistently out ranks the Tully and Johnstone Rivers (in that order), however, when combined with DIN load data, the mean risk values for the Russell-Mulgrave, Tully and Johnstone Rivers are similar. This indicates that for these rivers, it is the DIN load rather than discharge that is the primary determinant of the DIN risk score for these rivers.

The COTS Influence Index reflects the rankings noted above, showing that the DIN risk score for the Russell-Mulgrave and Tully Rivers is 70-75% of the Johnstone River, the Herbert River is 42%, Daintree is 34% and the Barron is 10%.

Combined assessment of the relative risk of degraded water quality in the Wet Tropics region to guide management priorities

A quantitative technique was used to combine the results of the marine assessment, end-of-catchment loads and COTS influence to generate a Relative Risk Index for each basin. These results show the greatest risk to each habitat in terms of the potential water quality impact from all of the assessment variables in the Wet Tropics region and end -of - catchment anthropogenic loads of TSS, DIN, PSII herbicides, PN, DIP and PP. The risk rankings are:

- **Coral reefs:** Highest ranking are the Tully-Murray and Johnstone basins. The primary land uses contributing to the pollutant loads in these basins are sugar cane and bananas. The rank of the remaining basins is Herbert (81% of the Tully Murray and Johnstone), Russell-Mulgrave (64%), Daintree-Mossman (42%) and Barron (34%).
- **Seagrass meadows:** Highest ranking is the Herbert basin. The primary land uses contributing to the pollutant loads in the Herbert basin are grazing and sugar cane. The rank of the remaining basins is Tully-Murray (82% of the Herbert), Johnstone (55%), Russell-Mulgrave (30%), Barron (14%) and Daintree-Mossman (10%).
- **Coral reefs and seagrass meadows combined:** Highest ranking are Tully Murray and Herbert basins. The rank of the remaining basins is Johnstone (85% of the Tully Murray and Herbert), Russell-Mulgrave (52%), Daintree-Mossman (29%) and Barron (26%).

From these findings, it can be concluded that ***the greatest risk posed to coral reefs and seagrass from degraded water quality in the Wet Tropics region is from the Tully-Murray, Herbert and Johnstone basins***. The relative risk of the Russell-Mulgrave basin is about half of the score of the highest ranking basins for the combined assessment, but higher when only coral reefs are considered (64%). The Daintree-Mossman and Barron basins are of lower priority relative to the other basins in the region (around 25-30% of the relative score of the highest ranking basins for the combined reef and seagrass result).

It should be noted that the confidence in the results at this time is low to moderate due to limitations in some of the input data related to river flows and pollutant loads for several variables in the model, particularly for the Johnstone and Russell Mulgrave basins (see Waterhouse et al., 2014). Accordingly, it is suggested that the results for these basins are likely to be an underestimate of the relative risk of degraded water quality in the region and that the Russell Mulgrave is likely to pose a greater relative risk than the analysis currently indicates. A number of relevant knowledge gaps are also incorporated in the research and development priorities identified in Section 10.

These results are summarised in Table 3.3 and have been used to derive management priorities in terms of pollutant types and sources for the region identified in Table 3.5.

Table 3.3. Summary of the outcomes of the overall assessment of the relative risk of water quality in the Wet Tropics region. Shading represents the following relative classes: Red = Very High (0.8-1.0); Dark orange = High (0.6-0.8); Orange = Moderate (0.4-0.6); Yellow = Low (0.2-0.4); No colour = Very Low (0-0.2)

Region	Basin area (km^2)	Annual Average River Flow (ML)	Zone of influence (km^2)	Marine Risk Index (based on marine assessment only)		COTS Influence Index	Basin Anthropogenic Load as a proportion of the Total Regional Load (%)						Loads Index	Relative Risk Index	Pollutant hotspots	Pollutant sources (anthropogenic loads)	Overall Rating of Relative Risk
				Coral Reef	Seagrass		TSS	DIN	PSII Herb	PN	DIP	PP					
Daintree	2,107	2,639,319	4,913	0.44	0.04	0.34	2	2	5	3	3	2	0.16	0.29		Sugar cane 26% DIN Sugar cane 99% PSII	**LOW**
Mossman	479	507,886														Sugar cane 65% DIN Sugar cane 99% PSII	
Barron	2,189	793,802	860	0.43	0.10	0.10	4	1	4	3	3	3	0.16	0.26		All cropping 9% DIN Cropping (except sugar cane) 66% PSII	**LOW**
Russell-Mulgrave	1,979	3,684,046	3,851	0.45	0.10	0.75	7	5	17	7	7	8	0.47	0.52	PSII 3 DIP 2	Sugar cane 60% DIN Sugar cane >99% PSII	**MOD**
Johnstone	2,326	4,559,029	2,649	0.67	0.12	1.00	13	19	20	19	9	22	0.94	0.85	TSS 2 DIN 1 PSII 3 PN 1 DIP 1 PP 1	Sugar cane 80% DIN Sugar cane 96% PSII	**VERY HIGH**
Tully	1,685	3,448,088	6,998	1.00	1.00	0.70	7	11	25	7	9	7	0.60	1.00	DIN 2 PSII 2 DIP 1	Sugar cane 74% DIN Sugar cane 96% PSII	**VERY HIGH**
Murray	1,115	1,290,985														Sugar cane 81% DIN Sugar cane 99% PSII	
Herbert	9,842	4,273,490	2,707	0.62	0.95	0.42	27	4	29	19	7	23	1.00	0.99	TSS 1 PSII 1 PN 1 DIP 2 PP 1	Sugar cane 88% DIN Sugar cane 97% PSII Grazing TSS	**VERY HIGH**

Table 3.4 identifies the priority pollutants for each industry in terms of relative risk to water quality. Where pollutants are not listed it is because they are low priority and are not seen as a significant issue in that industry's farming system.

When assessing potential water quality risk per unit area, Sing and Barron (2014) concluded that the Tableland mixed cropping system poses the highest risk to water quality in terms of pollutant load generated per unit area, primarily due to the timing of land cultivation. In mixed cropping preparing the ground for a December planting of peanuts or maize requires cultivation in late November to early December, just as the summer storms start. This practice results in a high level of loss of fine sediment, even under a contoured system, from the beginning of December through to the end of February when adequate ground cover is achieved by the peanuts or maize. The greatest area of mixed cropping occurs in the Barron basin, however, a majority of the area is located above Tinaroo Dam which provides a trapping mechanism for some of the material. However, when taking into account the overall loads of pollutants generated in the region, nutrients and pesticides from sugar cane and bananas are of greatest concern.

Table 3.4. Priority pollutants for each industry in terms of relative risk to water quality in order of importance. Source: Sing and Barron (2014).

Industry	Priority Pollutants in order of importance
1. Cane	Nutrients, Pesticides, Sediment
2. Bananas	Nutrients, Sediment
3. Mixed cropping	Sediment, Nutrients, Pesticides
4. Grazing	Sediment
5. Dairy	Nutrients

Table 3.5 summarises the draft priority areas for managing suspended sediments, nutrients and PSII herbicides in the Wet Tropics region, and identifies the land uses that are most relevant in managing those sources. The groupings represent overall relative priorities, and the basins are ranked from highest priority within those groupings (i.e. the highest priority for management is nitrogen in the Johnstone basin in sugar cane and bananas). However, the differences between priorities in nitrogen management in the Johnstone, Tully Murray, Herbert and Russell-Mulgrave basins are relatively small in the context of data uncertainties. For sugar cane only, the proportion of the basin currently at C class practices is shown as a simple indication of 'scope for improvement'.

Table 3.5. Summary of priority management areas for reducing the relative risk of degraded water quality to the Wet Tropics marine region. Source: Waterhouse et al. (2014).

Relative Priority	Priority management areas for GBR outcomes		
	Basin	Pollutant management	Key land uses
Very High	1. Johnstone	Nitrogen	Sugar cane (66% area currently C class practices), bananas
	2. Tully Murray	Nitrogen	Sugar cane (60% area currently C class practices), bananas
	3. Herbert	Nitrogen	Sugar cane (41% area current C class practices)
	4. Russell Mulgrave	Nitrogen	Sugar cane (Russell 85% area and Mulgrave 57% area currently C class practices)
	5. Herbert	PSII herbicides	Sugar cane
	6. Tully Murray	PSII herbicides	Sugar cane
High	1. Johnstone	PSII herbicides	Sugar cane
	2. Herbert	Sediment / Phosphorus	Grazing Disused mining sites in the Upper Herbert
Moderate	1. Johnstone	Sediment / Phosphorus	Sugar cane
	2. Barron	Sediment	Tableland mixed cropping; urban (broader Cairns area)
	3. Russell Mulgrave	Sediment	Urban (broader Cairns area)
	4. Barron	Nutrients	Sugar cane (53% area currently C class practices), urban
	5. Daintree-Mossman	Nutrients	Sugar cane (82% area currently C class practices)
	6. All basins	Phosphorus	Sugar cane, bananas, cropping, grazing, coastal urban
Lower	Barron, Daintree	PSII herbicides	Sugar cane

As part of the Source Catchments modelling in the region, Hateley et al. (2014) has undertaken an analysis of pollutant generation hotspots at a basin scale. These are summarised in Table 3.6. These results can be used to inform targeting of actions with the Wet Tropics basins.

Table 3.6. Summary of pollutant generation hotspots identified through the Source Catchments modelling for the Wet Tropics region. Derived from Hateley et al. (2014), Appendix K. The specific locations of the sub-catchments are available from DNRM.

Basin	Source Catchment modelling pollutant generation hotspots
Daintree	• Baird's Landing/Peirces Hill area (sub-catchment 3) was identified as a hotspot contributing a higher proportion of TSS loads.
Russell Mulgrave	• Babinda/Miriwinni area (sub-catchment 96) has been identified as a hotspot for TSS, DIN and PSII herbicides. • Babinda/Miriwinni area (sub-catchment 95) is a hotspot for TSS and PSII herbicides. • Babinda/Miriwinni are (sub-catchments 91 and 92) have been identified to contribute elevated PSII herbicide loads.
Johnstone	• Wangan/Mundoo (sub-catchments 115, 113, 122, 395) and Silkwood/El Arish (sub-catchment 150 () have been identified as a hotspot for SS and DIN loads. • Rankin Falls area (Sub-catchment 141) of the basin is a hotspot for TSS. • Silkwood/El Arish (Sub-catchments 147 and 149) have been identified to contribute elevated DIN loads. • Silkwood/El Arish (Sub-catchment 150) contribute high loads of PSII herbicides.
Tully	• Lower section of Travelling Dairy Creek (Sub-catchment 162) has been identified as a hotspot for TSS. • Areas Southwest of Tully (Sub-catchments 158 and 164) are hotspots for DIN and PSII herbicide loads. • Areas Southwest of Tully (Sub-catchment 393) contributes elevated PSII herbicide loads.
Murray	• Areas Southwest of Tully (Sub-catchment 177) has been identified as a hotspot for PSII herbicides.
Herbert	• Areas North of Ingham (Sub-catchment 194) has been identified as a hotspot for PSII herbicides.

3.3 Pollutant load reduction targets

3.3.1 Reef Plan Targets

End-of-system load targets for the major pollutants addressed in Reef Plan 2009 were set for the entire Great Barrier Reef in Reef Plan 2009 (Queensland Government 2009), and updated in 2013 (Queensland Government 2013). Neither set of targets were established on the basis of ecological realities for the Great Barrier Reef (GBR) although attempts to design targets of this type have been made (e.g. Brodie et al. 2009). There is no guarantee that the Reef Plan 2009 targets will lead to the overall Reef Plan objective of "*To ensure that by 2020 the quality of water entering the reef from adjacent catchments has no detrimental impact on the health and resilience of the Great Barrier Reef*". Reef Plan 2013 includes water quality targets and land and catchment management targets to be achieved by 2018, summarised below.

Reef Plan Water quality targets (2018)

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

- At least a 60 per cent reduction in end-of-catchment pesticide loads in priority areas. The PSII herbicides considered are hexazinone, ametryn, atrazine, diuron and tebuthiuron.

Reef Plan Land and catchment management targets (2018)

- 90 per cent of sugar cane, horticulture, cropping and grazing lands are managed using best management practice systems (soil, nutrient and pesticides) in priority areas.
- Minimum 70 per cent late dry season groundcover on grazing lands.
- The extent of riparian vegetation is increased.
- There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.

3.3.2 Defining Ecologically Relevant Targets

As part of the development of the WQIP, TropWATER has led the development of ecologically relevant end of catchment load reduction targets for the Wet Tropics basins (see Brodie et al., 2014). Ecologically relevant targets (ERT) attempt to define the pollutant load reductions that would be required to meet the GBR Water Quality Guidelines (GBRMPA, 2009), which are set at a standard considered to be suitable to maintain ecosystem health. Thus ERTs are required to be met to achieve the overall long-term Reef Plan goal "*To ensure that by 2020 the quality of water entering the reef from broadscale land use has no detrimental effect on the reef's health and resilience*". However, it is important to recognise that the Guidelines are defined to <u>maintain</u> ecosystem health, and given that the near and in-shore areas are already quite degraded, recovery is the only option. Accordingly, meeting the Water Quality Guidelines is unlikely to allow for significant restoration of ecosystem health, and therefore the levels at which recovery will occur will be lower than those at which stress on an ecosystem begins to occur to cause a detrimental impact.

ERTs have been set for all the basins in the Wet Tropics region, for the main pollutants addressed in the Reef Plan 2013 targets. Both sets of targets, Reef Plan 2013 targets for 2018 and ERTs, are shown in Table 3.7 and expressed as a percentage reduction from the modelled 2008 baseline estimates. The methods for deriving the ERTs vary between the pollutants. These are summarised below, and described in detail in Brodie et al. (2014). Based on current evidence, it is proposed that a feasible timeframe for achievement of the ERT is approximately 20 years from now, i.e. 2035. Beyond this period the influence of water quality improvement in the context of other drivers of GBR health such as climate change are difficult to predict. It should also be noted that additional external factors such as agricultural expansion, intensification of agricultural land uses, or increased pressure from coastal development have not been factored into this timeframe.

Total Suspended Sediments and particulate nitrogen and phosphorus targets

Ecologically relevant targets for suspended sediments are derived from understanding the impacts of sedimentation and turbidity on coral communities and seagrass meadows, and the relationships between end of catchment loads and turbidity in the receiving environment. The suspended sediment of most risk to the GBR is the fine fraction sometimes defined as that smaller than 15.6 µm, i.e. below the fine silt boundary and containing the clay and fine silt fractions (Bainbridge et al., 2012, 2014; Bartley et al., 2014) or of even more risk, just the clay fraction <4 µm. This is the component which contains most of the nitrogen and phosphorus content (and other contaminants), travels widely in flood plumes rather than all depositing near the river mouth (Lewis et al., 2014b) and drives increased turbidity on the inner-shelf of the GBR (Fabricius et al. 2013, 2014). This increased fine sediment supply and hence increased turbidity and sedimentation can have severe impacts on GBR organisms such as reef fish (e.g. Wenger et al., 2011), corals (e.g. Weber et al., 2013; Flores et al., 2013) and seagrass (Collier et al., 2012, Petus et al., 2014). Resuspension of sediment in windy conditions or strong tidal currents in shallow waters (<15 m) leads to conditions where suspended sediment concentrations are above the GBR Water Quality Guidelines (De'ath and Fabricius, 2008; GBRMPA, 2009) throughout the year, and this threatens coral reefs and seagrass meadows through reduced light for photosynthesis (Bartley et al. 2014; Collier, 2013).

Using this knowledge of ecological relevance and factoring in the availability of data, suspended sediment targets for reduction of the < 4µm fraction have been set. Numerical results are available for this fraction for relevant rivers from the GBR Catchment Loads Monitoring Program (e.g. Turner et al., 2013). In the future it would be desirable to shift this criterion to <15.6 µm to better reflect ecological relevance. Using the sediment size data will increase the target for reduction in total suspended sediment above the figures in the current ERTs.

The actual targets are derived from the analysis of the relationship between photic depth and river discharges in the region (Fabricius et al., 2014; Logan et al. 2014). The analysis shows a linear relationship between reduced fine sediment, particulate nitrogen (PN) and particulate phosphorus (PP) loads and Secchi depth (measured as photic depth) and indicates that a 50% reduction of the fine sediment fraction will be sufficient to generally meet the GBRMPA guidelines for Secchi depth (and thus TSS concentrations) for coastal waters. A reduction of 50% of the <4 µm load corresponds to varying overall reductions in TSS load for each river (normally in the range 10 – 25% reduction). An example of the analysis for the Tully Basin is shown below.

Example: Given for the Tully River, for example, the < 4 µm sediment fraction is 29% of the total sediment load, then a reduction of 50% of this fraction corresponds approximately to a 14.5% reduction in the TSS load (50% of the 29% fine sediment fraction). So our ecologically relevant target in this river is a 14.5% reduction in TSS, manifested specifically as a 50% reduction in < 4 µm fraction load which is also approximately equivalent to a ~50% reduction in PP and PN loads. However, there is currently inadequate particle size data to model specific sediment fractions in the Source Catchment model. As the % reduction needed for TSS will eventually be raised above 14.5% when data is available for the <15.6 µm sediment fraction, the modelled target should be left at 20% (which should achieve a 50% reduction in fine sediment).

The TSS targets for the other rivers for which < 4 µm data is available are as follows: Barron – 12%; Johnstone - 7.5%; Herbert – 11%. For modelling/analysis purposes at this stage the targets will be left at 20% reduction for all rivers.

Table 3.7. Summary of pollutant load reduction targets for basins in the Wet Tropics region. The table shows two sets of targets: Reef Plan Targets (RPT) and Ecologically Relevant Targets (ERT) for Total Suspended Solids (TSS), Dissolved Inorganic Nitrogen (DIN), Particulate Nitrogen (PN), Dissolved Inorganic Phosphorus (DIP), Particulate Phosphorus (PP) and PSII Herbicides (PSII). Source: Brodie et al. (2014).

River	Daintree-Mossman	Barron	Russell-Mulgrave	Johnstone	Tully	Murray	Herbert
TSS RPT	20%	20%	20%	20%	20%	20%	20%
TSS ERT[1]	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS	50% reduction in fine fraction (< 4 µm) SS
DIN RPT	50%	50%	50%	50%	50%	50%	50%
DIN ERT	50%	50%	70%	80%	80%	80%	80%
PN RPT	20%	20%	20%	20%	20%	20%	20%
PN ERT	50%	50%	50%	50%	50%	50%	50%
PP RPT	20%	20%	20%	20%	20%	20%	20%
PP ERT	50%	50%	50%	50%	50%	50%	50%
DIP RPT	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified
DIP ERT	50%	50%	50%	50%	50%	50%	50%
PSII RPT	60%	60%	60%	60%	60%	60%	60%
PSII ERT (diuron equivalent conc.)	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$	<0.08 $\mu g.L^{-1}$
PSII ERT (load)	0	0	82%	83%	73%	70%	90%

[1]Note that calculations of the TSS load reductions required based on actual particle size analysis from monitored data are available for the Barron, Johnstone, Tully and Herbert basins are presented in Brodie et al., (2014). These ERTs are typically lower than the ERTs presented above. It should be noted however that it is only possible to measure progress towards the 20% reduction in total SS using the Source Catchments model at this time.

Dissolved inorganic nitrogen targets

To determine ecologically relevant end of catchment DIN targets for Wet Tropics rivers the ChloroSim model was used (Wooldridge et al. 2006), which was used for DIN target setting in the Tully WQIP in 2006, using recent river concentration and end of catchment load data. A modelling framework was developed for the Wet Tropics region that links a quantitative river discharge parameter (i.e. DIN concentration in event flows) with an eutrophication health indicator (i.e. chl-*a* concentration) within the marine environment. The framework allowed us to calculate the catchment-specific level of reduction (%) in end-of-river DIN concentrations needed to ensure compliance with relevant GBR chl-*a* 'trigger' guidelines for the ecologically distinct (but DIN-related) issues of crown-of-thorns starfish outbreaks, reef biodiversity loss, and thermal bleaching sensitivity. Flood-plume sampling during the wet season indicates that DIN is largely conservatively diluted throughout the river plume volume up to salinities of 30 psu where DIN begins to be depleted by biological uptake. The risk of DIN-enriched flood waters reaching inshore, mid-, and even outer-shelf reef areas therefore increases considerably as end-of-river DIN concentrations rise. The ChloroSim model (Wooldridge *et al.* 2006) makes use of the conservative mixing properties of DIN to develop regionally-calibrated relationships that link: (i) end-of-river DIN concentrations, (ii) runoff:seawater dilution (a measure of flood intensity), and (iii) the ensuing flood plume intensity ('bloom') of phytoplankton biomass (as indicated by the concentration of photosynthetic pigment, chl-*a*). The general rationale behind ChloroSim is that for a given runoff: seawater dilution ratio, any broad-scale differences in the plume concentration of chl-*a* can be largely attributed to the initial concentration of DIN in the discharging runoff.

The original 2006 model calibrations were based on summer wet season chl-*a* data summaries (1992-2005) and end-of-river observations (1987-2003) that are described in detail by Wooldridge et al. (2006). To set ERTs for DIN currently we re-tested the central relationship that links the model nutrient enrichment parameter and the mean flood concentration of DIN with more recent data summaries (2006-present) for the Herbert, Tully, Johnstone, Russell and Baron rivers (Turner *et al.* 2013) and found the original calibration to be robust. Thus we utilised the ChloroSim decision support model to simulate: (i) the annual likelihood of exceeding 0.45 µg/L, 0.63 µg/L and 0.8 µg/L trigger values for the integrated flood plumes of the Wet Tropics river basins, and (ii) the uniform (%) reduction in end-of-river DIN concentrations needed to ensure compliance below these targets for all water within the GBR lagoon (Wooldridge et al. in review). However only the DIN targets need to comply with the 0.45 µg/L GBRMPA guideline are included in Table 3.7 as this is the threshold at which it is considered no adverse impacts will occur on GBR species and ecosystems due to DIN enrichment. The required reductions in DIN concentrations are then converted to a required DIN load.

PSII herbicides targets

The photosystem-II inhibiting herbicides are currently the main pesticides of concern in the GBR (and are thus the only ones specifically addressed in Reef Plan) and concentrations have been detected that are likely to cause negative effects in the freshwater, estuarine and marine environments. A new set of ecotoxicity threshold values have recently been proposed for marine environments (Smith et al., in prep) which have been developed to revise and update the Australian and New Zealand Water Quality guidelines. These proposed marine threshold values are available for the PSII herbicides diuron, atrazine, ametryn, hexazinone and tebuthiuron (and the insecticide imidacloprid) and have been derived using the latest ecotoxicological data and statistical techniques. It is likely that these guidelines will be adopted for the GBR Marine Park in place of the current GBRMPA (2009) values and are thus used in setting ERTs for these PSII herbicides in the Wet Tropics. We use the 99% ecological protection values for Australian marine environments at the end of river systems in the Wet Tropic Basins as (1) The 99% level of protection is in accordance with the current GBRMPA (2009) guideline's recommendations and (2) if the guideline is met at the end of the river then this ensures that no part of the Marine Park is negatively affected by a particular herbicide.

While the herbicide concentrations are of most importance to gauge their risk to receiving waters, the Reef Plan targets revolve around annual load reductions. Furthermore Reef Plan targets do not consider the 'toxic load' (i.e. the herbicides are considered of equal toxicity, although this is known to be not the case). Hence to develop ERTs we normalise the PSII herbicide loads to better reflect their toxic effects and then examine the reductions required to ensure that herbicide concentrations will remain below these ecologically relevant threshold concentrations. To do this the Lewis et al. (2011) model was updated with new monitored load data to produce the individual herbicide load estimations for the Wet Tropics basins. A PSII equivalent 'toxic' load was calculated using the proposed guideline values. The predicted PSII normalised (to diuron) 'first flush' concentration and the diuron ecotoxicity value (0.08 $\mu g.L^{-1}$) was then used to examine the likely reduction required to the end-of-basin loads so that the PSII herbicide concentrations would remain below these values. This analysis suggests that most basins of the Wet Tropics require a

70% or higher reduction in toxic PSII loads i.e. the ERT to achieve the guideline values (Table 3.7) although two basins require no reductions.

While an ERT is provided based on a load reduction, the guideline concentration (e.g. 0.08 $\mu g.L^{-1}$ for diuron equivalent) should be adopted as the actual ERT. Currently, the guideline is expressed as a single concentration for each level of species protection but in future this needs to be associated with an exposure period (e.g. 48 hours or 72 hours). A load ERT was calculated based on an EMC of a 'first flush' which roughly corresponds to a 72 hour period. The current load reduction estimates are likely conservative as they encompass the total annual load rather than just the first flush load.

3.3.3 Reef 2050 Long Term Sustainability Plan targets

In March 2015 the Reef 2050 Long Term Sustainability Plan (LTSP)[14] was released. The LTSP is a joint initiative between the Australian and Queensland Governments and provides an overarching strategy for management of the GBR, and contains objectives, targets and actions across several themes including: biodiversity, ecosystem health, heritage, water quality, community benefits and governance. The Plan builds on the Reef Plan targets as follows, by 2018:

- at least a 50 per cent reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads in priority areas, on the way to achieving up to an 80 per cent reduction in nitrogen by 2025;
- at least a 20 per cent reduction in anthropogenic end-of-catchment loads of sediment in priority areas, on the way to achieving up to a 50 per cent reduction by 2025;
- at least a 20 per cent reduction in anthropogenic end-of-catchment loads of particulate nutrients in priority areas; and
- at least a 60 per cent reduction in end-of-catchment pesticide loads in priority areas.

The longer term targets are comparable with the ERTs defined in this WQIP, however, the timeframes are more ambitious and the wording requires further interpretation to identify priority areas and the form of nitrogen under consideration.

3.4 Management options for directly reducing pollutant loads

The primary management options for directly reducing pollutant loads in the Wet Tropics are associated with improvement or maintenance of sustainable management practices that maximise water quality benefits in agricultural and urban land uses. However, many of these options do not result in immediate pollutant reductions at the end of catchments and are therefore required to be part of a longer term implementation strategy for meeting water quality targets.

3.4.1 Improving agricultural management practices

Management Practice Framework – ABCD for agricultural land use

The ABCD framework for agricultural management practices was developed as part of the Reef Plan Paddock to Reef Integrated Monitoring, Modelling and Reporting program (Paddock to Reef). It provides a consistent description of the levels of management practice moving from D or dated practices at the lowest level, to C practices at a level that may meet code of practice or legal requirements, to B practice that is known and generally validated best practice up to A practice which is believed may be even better practice but is unproven in an economic and environmental sense. Asking growers where they sit in relation to those practices assists greatly in assessing funding applications but also gives some indication of an industry's standing (i.e. its benchmark), at that point in time as well as indicating focal points for R&D and monitoring and modelling exercises. The framework has been adapted to be regionally specific and account for variation in specific practices that may be more relevant in a particular location or set of conditions.

The Wet Tropics version of the ABCD framework was the basic structure on which the Reef Rescue investments were made in the Wet Tropics NRM region, and has been recently modified as part of the 5 year investment cycle. The ABCD frameworks included in Appendix 4 are those determined for use in the WQIP and generally in the region for the next five years. Note that the framework used for the first five years of Reef Rescue investment is included in Sing and Barron, (2014); many practices remain the same. The framework is grouped by industry and pollutant, so for example CN 1.0 refers to Cane – Nutrients practice 1.0, and CS 16.0 refers to Cane – Sediment practice 16.0. The classifications

[14] http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan

and content were determined with advice from technical experts in the region (Terrain convenes a Cane Technical Working Group to guide Reef Programme investments), taking into account current, improving and emerging levels of industry knowledge and management. To distinguish the Wet Tropics /Terrain ABCD from others using the same terminology, it is commonly referred to as Terrain's ABCD or Terrain's Practice Change Tables. It was updated the Australian Government Reef Programme starting with Round 6 in 2014. Those changes included refinement of questions so as to be less ambiguous, thus requiring less interpretation and enabling more accurate response by the grower as well as more accurate data for practice change tracking over time.

Since inception of the ABCD systems, universal agreement on definitions of some of the categories has been difficult.

Some of the continuing uncertainty around A & B practices in relation to 'BMP' stems from

a) Mis-understanding of the range of certainty & achievability applicable to A class practices.

b) A desire to label something in particular as 'Best' management practice. There is likely no practical answer to the eternal questions of "Considered BMP by whom?" and "BMP under what set of climatic, topographical and geomorphological conditions?"

To attempt to clarify these, the Wet Tropics ABCD now includes an extra U/A category, (U being technically and / or economically unproven) and has a general understanding of the following categories (specific to the Wet Tropics region):

- **D practices** are agreed unacceptable or outdated practices.
- **C practices** are common practices that meet minimum legal requirements and some codes of practice, but which require further improvement for both water-quality and productivity.
- **B practices** are widely understood and accepted by industry, the agricultural-NRM sector and scientists, as good-quality practices for both water-quality and productivity that are quite achievable by viable growers, with the provision of some assistance eg hardware grants and/or training & extension.
  (This fits with the original Reef Rescue design of identifying regional priority practices and a goal of getting all growers to a realistic standard in a reasonable time period for a reasonable amount of incentive. Inherent in that was recognition that some acknowledged 'best' practices were simply not readily achievable by most growers within those time and financial constraints).
- **A practices** cover a range of practices from those that may be well researched, trialled and effective but are really out of reach of most growers (due to for example, high cost, poor cost: benefit ratio, long lead-time required for adoption, technical complexity, un-cooperative contractors etc), to those practices that are transitioning from experimental down to achievable.
- **U practices** or **U/A practices** are those in academically formative, experimental or early trial stages and are unproven.

One of the challenges of basing much of the reporting and modelling on the ABCD framework is the differences in the definitions of the levels of practice between reporting schemes and industry frameworks. For example, in the sugar cane industry, current BMPs will meet the Industry Standard under the Smartcane BMP framework[15] could be described as being roughly equivalent to C class practices under the ABCD framework, though there is some variability and this alignment is not so clear cut.

The Smartcane BMP has a 3- tier structure (Below /At /Above Industry Standard), which, though suiting its multi-regional and multi-themed (productivity, profitability and water-quality) application, is different to both the P2R and Terrain 4 tiered structure, making some comparisons fairly difficult. By nature of its wider scope and in comparison to Terrain's regional ABCD for example, roughly similar questions may have a different primary focus (eg in fallow, is the primary consideration extent of ground-cover or degree of tillage?), a similar question may contain more variables and combinations of them and some questions may also contain options within practices – all of which can compound the difficulty of direct comparison.

[15] https://www.smartcane.com.au/

It must be noted however, that all 7 of the Smartcane BMP modules, not just the 3 highest priority ones, contain some detail relating to improving water quality and the cumulative effect is both significant and holistic. The Smartcane BMP is also the only system that requires proof of practice and this will be of immense use in long-term monitoring of practice change.

Table 3.8 illustrates the alignment of the description of classes of practice in the Wet Tropics region. Figure 3.13 is also an attempt to represent that alignment diagrammatically. With co-operation between sectors a stronger alignment between systems should progress over time.

Another issue is continual improvement of the water quality benefits of practices as they evolve with better knowledge. For example, as an A class practice becomes proven and accepted, it is then adopted by industry and becomes a B class practice. The use of GPS for zonal-tillage / permanent beds in the sugar cane, banana and multicrops industries is an example. Similarly some surface-fertilising practices that have been accepted as B practices due to previously limiting factors are likely to move to C class practice as existing methodologies are proven to be applicable and new trials confirm water-quality impacts. It is important to recognise and capture this shift in evolving practices, and reflect what is actually happening on the ground rather than be constrained by categories. Hence, it is recommended that the framework is shifted into the context of water quality risk posed by management practices. This is being progressed through the Paddock to Reef Program for each region.

Table 3.8. Alignment of the description in management practice classes under the Reef Plan Paddock to Reef Program, Wet Tropics Reef Rescue programs and the Smartcane BMP framework.

<table>
<tr><th colspan="2">P2R WQ Risk Assessment</th><th rowspan="2">Terrain</th><th rowspan="2">Smartcane BMP</th><th rowspan="2">Description</th></tr>
<tr><th>Previous</th><th>Current</th></tr>
<tr><td rowspan="2">A</td><td rowspan="2">Lowest Risk: Innovative</td><td>U/A</td><td rowspan="3">Above Industry Standard</td><td>Unproven for economic & environmental outcomes.</td></tr>
<tr><td>A</td><td>Ranging from partially to largely validated practices which are still out of reach of most growers.</td></tr>
<tr><td>B</td><td>Best Practice</td><td>B</td><td>Known & validated, high-quality practices</td></tr>
<tr><td>C</td><td>Minimum</td><td>C</td><td>Industry Standard</td><td>Common practices that meet legal requirements and some codes of practice</td></tr>
<tr><td>D</td><td>Superseded</td><td>D</td><td>Below Industry Standard</td><td>Not supported.</td></tr>
</table>

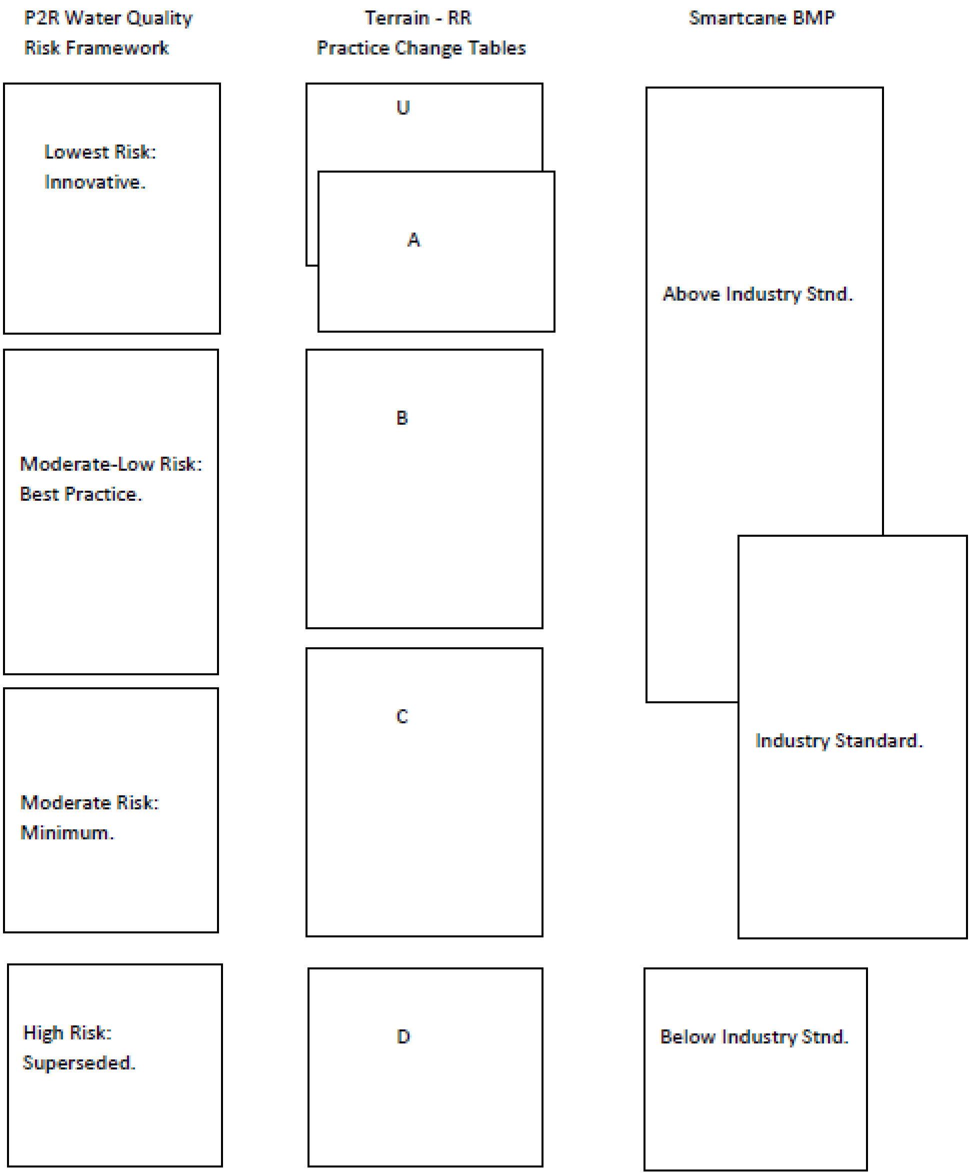


Figure 3.13. Alignment of the description in management practice classes under the Reef Plan Paddock to Reef Program, Wet Tropics Reef Rescue programs and the Smartcane BMP framework.

3.4.2 Management practice effectiveness

A comprehensive review of the likely effectiveness of specific management practices in reducing DIN, PSII herbicides and suspended sediment was undertaken as part of the supporting information for the development of the WQIP (Sing and Barron, 2014). It is based on informed opinion that stems from recent research from a range of sources. Given that cane related issues have been subjected to more research they are likely to be better informed judgements than they are with bananas.

Table 3.9 shows the relative potential effectiveness of a range of cane management practices. These values have been derived from expert opinion using a number of technical experts in the region. The total percentage in each column adds to 100%. This summary is then followed by a discussion of each activity/practice in more detail.

A similar summary is provided for bananas in Table 3.10. For bananas, the practices associated with Bn 19, Bn36 and Bn37 are all connected by the ability to fertigate. However, the ability to fertigate (Bn 19) does not guarantee the level of performance in the other two practices.

Table 3.9. Summary of management practice effectiveness – Cane. Source: Sing and Barron, (2014).

Practice	Effectiveness in reducing DIN	Percent effectiveness in reducing PSII	Percent effectiveness in reducing sediment
Cn3.0 Rate of fertiliser use	55% high	N/A	N/A
Cn4.0 Timing of fertiliser application	20% medium	N/A	N/A
Cn5.0 Placement of fertiliser	10% low	N/A	N/A
Cp12.0 Herbicide application technique timing, Cp36 Spraying equipment	N/A	60% very high	N/A
Cp 32.0 Residual use in plant crops	N/A	15% medium	N/A
Cp 33.0 Residual use in ratoons	N/A	15% medium	N/A
Cn16.0 Row spacing	10% low	10% low	60% high
Cn17.0 Cultivation prior to planting	5% low	Low	20% medium
Cn21.0 Riparian management	Very low (relative)	Low	5% low
Cssd 22.0, Csdp 22 and Cs 40.0 Drains and headland management	Very low (relative)	Low	15% medium

Table 3.10. Management practice effectiveness – bananas. Source: Sing and Barron, (2014).

Practice	% effectiveness in reducing DIN	% effectiveness in reducing sediment
Bn 19.0 Irrigation method	10% Low	N/A
Bn 34.0 Fertiliser rates	55% High	N/A
Bn 36.0 Fertiliser frequency	20% medium	N/A
Bn37.0 Fertiliser application method	15% Low	N/A
Bs 1.0 Cultivation method – timing of land preparation	N/A	33% High
Bs 26.0 Contouring for run off water	N/A	33% High
Bs 30.0 Ground cover	N/A	33% High

New research indicates that an even greater proportion of the Total N loss from bananas than previously estimated is as particulate N associated with sediment loss (Armour et al., 2014). This, coupled with the industry's own opinion that run-off management, with its combined impact on both direct nutrient loss and indirect loss by soil movement, will result in surface-drainage and ground cover management having an increased weighting in relation to other practices from this point on.

The management practice options for DIN, PSII herbicides and TSS are listed below. The impact of each of these options is described in Sing and Barron (2014).

Nutrients, particularly Dissolved Inorganic Nitrogen

Sugar cane nutrient management practice options

The management practice options for DIN are all aimed at reducing the nitrogen surplus at high risk times of the year so the priorities will be the management practices that are the most effective in this regard. High N rates on cane in July will lead to a high N surplus but may not necessarily result in severe water quality impact as it may be partitioned into progressive uptake by the plant under favourable conditions, loss by volatilization and, denitrification, and returning to soil reserves by mineralisation (incorporation into the soil organic matter) before losses to deep drainage or runoff can occur. However, where there is insufficient time between application and heavy rainfall to allow N adsorption onto soil particles and be available for crop use and where other loss pathways (none of which are desirable even if there is no water-quality impact), do not reduce the surplus available for loss, high rates (surplus to uptake) late in the year during the storm season or close to the wet season, will have a similar N surplus but with a very high risk of loss into the water table. Whether or not nitrogen surplus is a problem for water-quality is thus time and weather dependent.

Recommendations in the past included:

- Sub- surface placement of fertiliser;
- Variable- rate application of nutrients;
- Adoption of 6ES 'Six Easy Steps' recommendations; and
- Adoption of new farming systems.

Additional options in the future include:

- Refining assessment of rates using block and farm yield potential along with district yield potential;
- Geo- referenced nutrient management zones, (various combinations of precision soil, yield, EM, satellite mapping);
- Extension to encourage tailored nutrient rates for high risk locations, time of the year, late harvested crops and parts of the crop cycle;
- Application of slow release fertilisers; and
- Improving nutrient availability through improved soil health.

Impact of these options:

1. Sub- surface placement of fertiliser

Work by Reghenzani and others as part of Prove et al. (1997, details unpublished), indicated reductions of 20 kg/ha of N for subsurface placement centre stool and 15 kg/ha sub surface side stool. Prasertsak et al. (2012) indicated such savings were possible. However, work by Webster et al. (2012) indicated such fertiliser practices can result in higher leaching losses, therefore results are equivocal. There are a number of factors that suggest that subsurface placement should no longer be a priority for investment. These are:

1. Sub surface application is reported to be already used on 88% of land under sugar cane in the Wet Tropics so few benefits if any are left to be gained.
2. Sales data from Incitec Pivot showed that the average rate of N application was 143 kg/ha prior to Reef Rescue and there has been no sales data to substantiate that usage rates have now dropped by 20 kg/ha. Claims were made by farmers that sub surface fertiliser placement would allow them to drop rates but this change has not been substantiated.
3. The ambiguity over the benefits of sub surface placement due to concerns with higher leaching and potentially greater rates of denitrification in waterlogged soils.

Counter arguments are:

- The use of sub-surface fertilising increases over-all nitrogen-use efficiency (NUE). There may be some argument about the relative proportions of loss pathways for surplus N (leaching, surface-runoff, volatilization, denitrification and return to soil reserves by mineralisation). However, a message to growers that very significant loss to the atmosphere by volatilization and denitrifcation is ok because that surplus N is then not available for leaching or run-off, is not helpful in the quest for overall NUE. The accurate matching of rates to crop requirements is dependent on the maximum possible NUE.
- Those who are still not sub-surface fertilising (without good reason) are likely to also be behind in associated practices eg. correct rates. A funding option is that illustration of correct rate-assessment would be a specific prerequisite for funding of for example, a fertiliser applicator. This would be a progression from the current

arrangement in the Wet Tropics that requires recipients of nutrient related grants to develop a formal Nutrient Management Plan by the end of the contract period.

2. Variable rate application of fertilisers

Variable-rate fertilising (VRF) has application in all industries as it is an essential component of true precision agriculture. Eventually, having fertilising hardware with the ability to easily vary rates as the tractor goes down the row (i.e. manually with the turn of a dial or automatically by computer controllers), will be matched to precision application maps based on some combination of GPS-referenced soil, EM (electromagnetic), yield and satellite mapping. Until that time however, there is still value in adopting VRF. Even variations of rates based on fairly coarsely determined 'management zones' i.e. rich-flood land versus less fertile higher ground or well-drained vs poorly drained portions of blocks, can result in significant N reductions on some farms. More importantly, providing incentive to install VRF capacity on fertilising equipment, simply makes it easier for growers to incrementally adopt varying degrees of VRF sophistication as they become available. For these reasons, any fertilising equipment funded under the Reef Programme in the Wet Tropics has to have VRF capability. Though impacts on DIN losses from this practice have not yet been well quantified at farm-level, the potential for reductions on a regional scale is very high.

3. Greater adoption of 6ES as a result of training

The benefits of funding of any equipment depend on it being used to its best advantage. This premise was the basis of funding of 6ES in Reef Rescue I. 6ES is a complete nutrient management approach, not merely one for nitrogen. Adherence to its principles would ensure a balanced nutrient regime without any of the major, minor or trace elements being a limiting factor and without any element being applied in unproductive excess. An absolute key factor is an understanding of the soils on a property and their relationship to crop nutrient requirements. An often overlooked aspect is the constant review and refinement of a nutrition program through quality record keeping and access to expert advice.

Though there has been a much greater participation in 6ES courses and regional experience indicates that the Reef Regulations did lead to more soil testing, there is some concern that in some cases this did not necessarily translate into more detailed nutrient assessment and more appropriate N rates. There are many reasons why this may occur – ranging from varying levels of grower acceptance of 6ES principles, through the lack of ability to easily adjust rates on a machine, down to available blends of fertiliser not being exactly right for a given situation. Even with this obligation, anecdotal evidence suggests that a lot of farmers on at least one block on their farm ignored soil testing results and advice, and applied a different (often elevated) amount of N. The economies gained from scale purchasing of fertiliser also means that small sized multiple fertiliser mixes are not viable/profitable for merchants/providers to produce, leading inevitably to a less than perfect rate being used on many blocks of cane.

As a result of the above realities/complexities, the impact of 6ES training on DIN losses is not currently quantifiable as the changes farmers made as a result of the training are not accurately known.

4. Adoption of whole farm management systems

The essential components of 'new' farming systems are those identified by the past Sugar Yield Decline Joint Venture (SYDJV). They include reduced compaction, reduced tillage, break-cropping, increased soil heath and precision application of inputs. They all have water-quality as well as productivity implications. Controlled traffic /compaction and reduced tillage are considered high priority features. Any practice that improves soil water holding capacity, improves the plants ability to take up nutrient and reduces runoff and sediment losses will also reduce N losses, although to differing degrees and will be less important if rates are not also considered. Runoff water contains both dissolved and particulate nutrients. Masters et al. (2008) showed that controlled traffic reduced N losses by 11%. Controlled traffic also reduces compaction and reduces area of tillage, resulting in improved soil health and healthier cane plants. Until now, no overall farm production benefits have been quantified but higher yields per ha have been common. Blocks where controlled traffic is used indicate production benefits over non controlled traffic blocks in wetter years.

The promotion of whole farm management systems is justified on the grounds that the cumulative effects of its components has the potential to reduce nutrient and sediment losses directly as well as PSII herbicide losses indirectly.

5. Additional future options

There are a number of options for managing N surplus listed above that should be explored and encouraged in the future. The fundamental concepts are associated with tailoring rates relative to soil types, and the timing of application. Utilisation of geo referenced soil zones is part of the management of N surpluses where N is applied at a rate appropriate for the soil types identified within the geo referenced soil zone / nutrient management zone. Soil characteristics have important implications for yield, for example, sodic soils (lower yield), waterlogged soils (lower yield) or organic rich soils (higher yield) etc. This approach assumes that the soil within a particular soil/management area is reasonably homogenous and can respond consistently to N applied. Thus, an appropriate N rate for that particular portion of a block or farm can be calculated and applied so that N surpluses will be minimised. It also assumes that the rate used is appropriate for the soil type within the block and not merely based on a district yield potential as occurs under a broad brush 6ES approach. Extension as follow up to training programs is likely to be an important influence on ensuring greater adoption of the full 6ES concepts.

As an example, with actual yields quite capable of varying between 50t/ha and 160t/ha within a 10ha block, use of the 6ES rate of 140kgs/ha will result in much of the block being over fertilised and much being under fertilised so that fertiliser is wasted on one part of the block but not enough applied 100 metres away. Work by Webster et al. (2012) showed that reducing N fertiliser applications by 47% reduced DIN by 60% in runoff. Such reductions are feasible in the example above. The lower yielding part of the block may be restricted in its ability to respond to higher rates of N by drainage, soil structure or sub soil fertility and fertilising this area at district yield 6ES rates is simply a waste of money.

The rate of application is also critical. In the past 6ES has recommended that farmers use district yields plus 20% to determine the rate of N used. However the 6ES training was always assumed to be followed up by on farm nutrient management planning on a one on one basis to fine tune the N requirements to the individual property. This targeted progression/further extension to shift to block yields versus district yields has not been progressed and this option recommends that nutrient management planning should be completed.

There are a number of on- farm scenarios/situations where N rates could be considered for reduction (within the context of achievable yield) including:

1. Crops harvested after October, which usually produce lower yields no matter what part of the crop cycle stage they are at.
2. Older ratoons which are going to produce lower yields.
3. Crops requiring fertilising in November in the face of an approaching forecast heavy wet.
4. Crops in a risky location on the farm e.g. on a significant slope close to a waterway.
5. Crops in blocks that have a documented history of low yields resulting from paddock conditions e.g. waterlogging, consistent flooding, sodic or other poor soil characteristics.

All of these scenarios are very farm and season specific situations and are best addressed by one on one extension. Some larger farmers (>200ha) may respond to precision 6ES training but the training approach does not allow quantification of the results. This quantification of reduced N applications can only be achieved by a one on one approach. The size of the DIN impact can be judged by the likely reduction in N applied which could range from none applied in scenario 3 above to as little as 10-15% less N applied in scenario 1 and 2 above.

Note that the A practice as listed in the Wet Tropics ABCD does not articulate this approach in sufficient detail to guarantee that adoption of A practice as listed is consistent with the above points.

Research regarding slow release fertilisers in far north Queensland is in the very early stages and this is acknowledged in Thorburn et al. (2013). It appears that it does have the potential for 30% reductions in the rate of N used not only in sugar cane but also in bananas and dairy industries where research is also being done on this form of fertiliser (Armour et al., 2014; Rowlings et al., 2013).

Extension services need to be focused into high risk areas, described further in Section 8. In the Wet Tropics region, 170 farmers farm 60% of the cane which in itself is a beneficial situation for focusing extension services. The harvesting season in the Wet Tropics lasts about 19-22 weeks depending on the incidence of rain during harvesting and stoppages at the mill. Harvesting can continue almost up to the second week in December in worst case scenarios or finish in late October. With the latter, risks are reduced but with the extended season, risks of N losses are high with N fertilisers applied after harvest and consequently very close to the wet season commencing in earnest. Under late season conditions as much as 20% of the N applied is done so under very risky conditions.

<u>Banana nutrient management practice options</u>

The most significant feature of N use in relation to bananas is that over the last decade common rates of N have dropped from 550-600 kg/ha to around 300kg/ha. There are a number of reasons but major among them is increased research and extension effort.

Current options for reducing DIN from bananas include:

- Targeted nutrient management approach to N applications;
- More widespread use of fertigation;
- Refinement of surface, banded applications; and
- Slow release fertilisers.

Impact of these options:

1. Targeted nutrient management approach
Similar to other industries, the prime consideration is the matching of crop inputs to crop requirements.

Regular and frequent soil and leaf testing, matched to industry recommendations is the basis for accurate assessment of N rates. These would be appropriate for the requirements of the crop at a particular crop-stage and at a particular time of year, on specific blocks. They would be monitored against yields to assess their effectiveness. Reduction of N surpluses reduces loss by all pathways including as DIN in deep-drainage (leaching) and surface run-off and as particulate N in transported sediment. This is an extension issue and to date, very significant improvements have been made through grower use of both industry extension and private consultant services. Some banana farmers however, are still using rates in excess of 400 kg/ha. Increased adoption of the nutrient management recommendations contained in the industry's own Banana BMP ("Banana Best Management Practices – Environmental Guidelines"[16]) would identify and help address the issue of surplus N application.

2. More widespread use of fertigation
This option has already been widely funded, especially the move from manually operated to automated fertigation systems. Consequently, more than 1000 hectares have changed from overhead to under tree sprinklers with fertigation capacity and 65% of the industry now has fertigation capacity, up from 56%. The average N rate used is 292 kg/ha (source Sing Industry Survey 2011) but anecdotal evidence is that farmers do reduce their rates by as much as 50kg per ha when they move to fertigation. It should be noted that this 50kg reduction is not necessarily from the average of 292 kg/ha as this rate incorporates the reductions that have already occurred to date. A more likely reduction in N rates from 292 kg/ha down to 275 kg/ha or a 6% reduction is directly attributable to fertigation. More important than the reduction is the reduction in risk where N is applied every fortnight instead of every 4-6 weeks with a commensurate reduction in the amount applied each time so that the potential for losses as a result of high rainfall events is significantly diminished.

3. Refinement of surface, banded applications.
Where growers do not have fertigation and where it is not appropriate (i.e. during wet-weather), surface application is acceptable when it is accurately banded on the row, is applied in small amounts frequently (monthly or more often) and is watered in - either by rainfall or irrigation. The risk of untimely heavy rainfall cannot be entirely eliminated but is ameliorated by the small dosage of nutrient to the crop at any one time. Recent research (Armour et al., 2014), has shown that DIN losses under this system, if managed well, can be, as low as losses from fertigation.

4. Slow release fertilisers
As in other agricultural industries in the Wet Tropics, the use of slow release fertiliser, is not well validated at this stage, though significant trials are in progress. It is however, recognised that there is a high potential for reduction of N losses if they live up to their potential. Their use as a wet weather complement to dry weather fertigation has particular promise. The three main types of products considered are a) polymer-coated formulations, b) urease inhibitors, and c) conventional product in biodegradable sachets. Significant issues applicable to bananas are high product cost in all cases and high labour costs in some. Though not directly applicable to reduction of DIN, the reduction of total N losses from bananas via sediment loss is increasingly seen as the banana industry's major challenge. Where DIN loss via deep drainage may vary from 30kg/ha/yr in a plant crop (1 yr in 8-10), to only 1.5kg/ha/yr in ratoons, losses of total N associated with runoff and soil movement can be in the order of 5-60kg/ha/yr (Armour et al., 2014). The higher rates seem to be particularly associated with poor ground-cover and sediment transport.

[16] Qld Dept Agriculture, Fisheries & Forestry / Horticulture Aust Ltd / Aust Banana Growers' Council.

Given this very strong relationship between nutrient and sediment management, future funding and extension effort is very likely to focus on strategies that address them in combination.

Mixed cropping nutrient management practice options

Peanuts and maize are the two Tablelands crops planted in November/December and maize involves potential N losses at this time of the year. Peanuts do not require any N, as they fix their own N requirements. Rates used on maize are extremely variable and no data is available on average rates applied. Potatoes and grass seed crops are also heavy users of N particularly potatoes but the former are winter planted so at a low risk time of the year and are mostly irrigated. No recommended practices are available to reduce N rates for any of the Tablelands mixed cropping scenarios. Tablelands farmers typically already reduce N rates on crops grown after peanuts and potatoes because of carryover of N from these crops. Soil testing is already carried out by mixed cropping farmers at a reasonably high level compared with sugar cane farmers[17].

The only solution to reducing DIN losses from Tablelands Mixed Cropping is to reduce fine sediment losses and this is much more difficult. See discussion under Suspended Sediment.

Dairy nutrient management practice options

Results from a recent survey (K. Shaw pers. com.) showed a direct relationship between N applied and milk production per cow, and is only limited by the farmer's ability to pay for the N. Options to reduce DIN losses include:

- Slow release fertilisers (Rowlings et al., 2013).
- Recognition of a 'degree day' concept which acknowledges that on the Tablelands it is temperature that can restrict pasture growth not N levels. So N applied where temperature limits growth and wet weather occurs will thus be lost. This concept needs further research but this is unlikely with most dairy research under COAG occurring in Victoria and not Queensland.

PSII Herbicides

Sugar cane PSII herbicide management practice options

Options for the reduction in the loss of PSII herbicides to the waterways include:

1. Aiming to not apply any residuals within 30 days of the commencement of the wet season (implies greater use of forecasting)
2. A strategic approach to weed management where weeds are controlled using residuals in fallow crops and plant cane but are not used in ratoons. (Note: the crop cycle in north Queensland normally consists of a fallow crop, plant crop and four ratoons so any part of the crop cycle is only one sixth of the total)
3. Banded spray applications
4. Hooded sprayers.

Impact of these options:

1. Not using residuals within 30 days of the start of the wet season.
The importance of application timing is well covered in the Scientific Consensus Statement (SCS). For example Rohde et al (2013) found that 90% of herbicide was lost in the first 11 millimetres of runoff where heavy rain occurred within 20 days of application.

Practice change in this area is partly dependent on extension effort that can illustrate the loss of effectiveness of herbicides when rainfall occurs too close to the date of application, before either the plant (in the case of knockdowns) or the soil (in the case of residuals) has had sufficient time to absorb or adsorb the active constituents.

There are numerous considerations. Prediction of the storm & wet-seasons, let alone individual rainfall events, is very difficult. The presence of very hot & dry conditions during that pre-wet-season window may preclude spraying at all and planting and harvesting timing, influenced by a myriad of factors earlier in the year, has an impact on the stage and vigour of weed growth during critical spraying windows later in the year.

[17] Paddock to Reef Program 2008 Survey results for tableland farmers compared to Incitec information.

The potential for improved timing of residuals is governed largely by other aspects of strategic weed management and the overall farming system. The degree of late weed pressure, the trafficability of paddocks during critical related operations and other efficiencies that allow an availability of time to utilize critical weather windows are examples.

This practice is considered 'aspirational' as the risk of poor weed control in one year is high weed pressure in subsequent years. Despite that the potential for both improved efficiency of herbicide use and improved water-quality, is high.

2. Strategic approach to management of weeds
One of the main priorities of integrated weed management is to utilise all available weed control options in a strategic manner. The goal is to reduce seed banks and the subsequent germination, growth and distribution of weeds across the farm. A planned approach to using residuals is an essential part of that as a) they have an important role to play in preventing germination, but b) have good potential for a reduction in use as they are sometimes used either inefficiently or in situations where other cheaper options, with lower water-quality risk, could be utilised. There are hugely varying situations, with super-wet areas being the hardest to balance the twin issues of high weed pressure and high loss potential. Waiting until maximum weed germination has occurred and the crop needing to be sprayed only once, may result in seed production and subsequent problems, whereas spraying twice, when the weeds are smaller at lower rates, may result in a cleaner paddock in the longer term.

In the Mossman catchment 72% of farmers[18] do not use residuals on ratoon crops instead only using knockdowns, indicating that strategic management is quite achievable. However, even though residuals are not used on 66% of the crop area in the Mossman region, load levels in the Mossman basin are still 3% of sales of PSII herbicides (N. Sing, pers. comm.), hence the need for the option 1. Other catchments have varying degrees of adoption, but generally this approach has a long way to go before a majority of farmers are using it.

3. Banded sprayers
Potential savings in losses of PSII herbicides are covered comprehensively in Thorburn et al. (2013). Banded / directed spraying can reduce the use of residuals, including PSII herbicides by up to 50% by applying them to the row only (roughly 50% of the paddock area), leaving control in the interspace to other methods. Examples are the use of knockdowns in the interspace by hooded sprays and variations of ground level directed sprays as well as targeting of tall or climbing weeds (eg vines) in advanced cane rather than blanket application.

4. Hooded sprayers
The use of hooded sprayers has been funded widely (in Reef Rescue 1), potentially allowing knockdowns (including glyphosate which is deadly to cane), to be used more readily in ratoon crops as a substitute for residuals, including PSII herbicides. Technical advice from former BSES officers has been that these hooded sprayers are more of an adjunct or a complementary measure to the higher priorities of strategic weed control and timing of residual application (1 and 2 above).

Banana PSII herbicide management practice options

Pre-emergents /residuals are used only occasionally in bananas and therefore PSII's are not considered a significant risk. Insecticides and fungicides are frequently used but generally in small quantities with very targeted application. Fungicides are used on leaves and tend to be found at very low concentrations in the environment. Bunches tend to be either spot sprayed under the bunch cover or treated via a pesticide impregnated strip, which is recycled. An extension push informing about the strategic use of insecticides and increased application of integrated pest management has resulted in dramatic drops in insecticides used and it is estimated that pesticide use has reduced as much as 90% in last 20 years (S. Lindsay, *pers. comm.).*

Mixed cropping PSII herbicide management practice options

PSII herbicides are regularly used in mixed cropping, particularly in maize where failure to do so can result in a crop not worth harvesting because of infestation with hops. Strategic solutions are not available as ground preparation for maize

[18] Reef Rescue 2011 weed survey, N. Sing Terrain NRM.

is undertaken after the first storms have occurred in November/December. PSIIs pose a significant risk, as with cane, because of proximity to rainfall events and loss in runoff and also from loss through attachment to sediments.

Management options are limited but could include planting slightly earlier with irrigation so that there is more groundcover before the onset of the wet however this is unlikely to be economically viable as maize is a low value crop.

Suspended Sediment

Grazing TSS management practice options

Options are:

1. Reduced stocking rates
2. Targeting erosion hot spots
3. Fencing off rilled areas, gullies, and river frontage paddocks to enable better management of those areas in non-rainforest areas and sodic soil areas,
4. Best practice road maintenance and construction, and fence line clearing.

Impact of these options:

1. Reduced stocking rates

The Reef Plan Scientific Consensus Statement (Thorburn et al., 2013) highlights the impact of excessive forage utilisation on erosion, including degradation that can occur before a decline in pasture productivity can be detected. Excessive stocking can also reduce cattle productivity so reducing stocking pressure can be a win-win situation for the beef producer and the environment.

Fencing of riparian areas or other areas at risk is not successful unless stocking pressure is reduced. In Reef Rescue 1 fencing off riparian areas was a common investment but no data was available to inform funding providers what happened to stocking pressure and pasture utilisation on the remainder of the property. Fencing riparian areas enclosing frontage country enables better management of that country so that it is not overgrazed but it is no guarantee that this improved management actually occurs or that stocking pressure is reduced.

As mentioned in the Reef Plan 2013 Scientific Consensus Statement (Brodie et al., 2013, and more specifically Thorburn et al., 2013) the benefits to sediment loss can be considerable. However, the Upper Herbert with poor soil fertility is an area regarded as breeding country where young stock are sold off for fattening elsewhere. This approach leads to a herd composition with a high proportion of drought vulnerable breeders and a more limited ability to destock without selling breeders, unlike country where fattening is undertaken. An added problem is a common misconception that there is a positive correlation between high stocking numbers and greater financial returns.

Another problem is that high stocking rates are often found on properties that do not have much involvement with DPI&F (now QDAFF) or their own industry organisations so it is difficult to engage these land managers.

Despite the above challenges, the primary solution for these producers who have degraded properties is through extension and using financial incentives to cooperate, however, these options alone may not provide the gains required especially in the longer term. Other more innovative solutions to promote uptake are required.

2. Targeting hot spots

Many of the erosion hotspots are old mining sites in the Upper Herbert which because of their degraded nature and potential impact, may require fencing and engineering works. Unlike gully remediation which can be high cost with uncertain chances of success, fencing of tailings piles and degraded areas may have more chance of success particularly if, without intervention, further degradation with significant impact is highly likely.

3. Fencing off areas at risk

Fencing of gullies, riparian areas, and sodic soil areas with permanent stock removal is a way of increasing ground cover. However if stocking rates above these areas remain the same and erosion continues then the benefits will be nullified. Sodic soil areas are frequently overgrazed because cattle tend to prefer the grass from these areas.

4. Best practice road and fence line construction

Work in the Mitchell and Normanby catchments has shown that considerable sediment loss can occur from badly designed on-property road construction or fence line clearing that also requires frequent and substantial maintenance (Brooks et al., 2013). Best practice road construction is a more cost effective solution in the first place.

Cane TSS management practice options

Options are:

1. Surface drainage and farm layout.
2. New farming systems adoption
3. Best practice drain modifications
4. Good fallow management (ensuring ground cover & minimal tillage)
5. Green cane trash blanket (but this is already widely adopted in the region)
6. Grassed headlands

Impact of these options:

1. Surface drainage & farm layout

These themes involve the shaping of the surface profile of blocks and the orientation of the row direction within those blocks, to carefully shed excess water without causing soil erosion or water-logging as well as the coordination of the subsequent runoff from each block on the farm so that it in turn is firmly but slowly directed to a safe destination. Contouring, grassed waterways and sediment trapping are high-end examples from steeper country, but the simple establishment of uniform, suitable grades that complement row direction within a block on any degree of slope and which feed into an organised drain system, are the majority case. The issue of appropriately shaped, grassed and well maintained headlands is also related.

2. New farming systems

Masters et al. (2013) showed that controlled traffic is effective in reducing runoff and soil loss. With the added benefits of reduced nutrient and pesticide runoff it makes the adoption of controlled traffic a high priority. It has also been suggested (Hanks pers.com.) that controlled traffic allows earlier use of residuals in plant crops, thereby reducing the risk of losses with more time for chemical degradation before heavy rains.

3. Best practice drainage

Roth et al. (2003) showed significant sediment losses occurred from badly constructed drains. Appropriately constructed drains are a relatively cheap solution and did not previously exceed more than 5-8% of Reef Rescue grant allocations.

4 & 5 & 6. Good fallow management / green cane trash blanket / grassed headlands

The most commonly considered aspects of fallow management that relate to sediment issues are ground-cover and tillage. Consolidated (uncultivated) soil and substantial groundcover have the lowest potential for soil loss. The absence of both has highest potential losses and the use of each on its own can be either ok or poor depending on other paddock and weather conditions. There is a very pronounced positive multiplier effect when these practices are combined with the other aspects of sediment control, particularly surface drainage and farm layout.

Bananas TSS management practice options

Options are:

1. Contoured banana blocks
2. Permanent beds
3. Grassed inter rows
4. Fallow management (ground cover)

Impact of these options:

1 & 2. Contoured banana blocks/permanent beds

When a block of bananas is taken out at the end of a crop cycle, there is opportunity to reconfigure the block so that new plantings are aligned (with professional advice) to match the contour. If a move to permanent beds (which has further benefits re: reduced cultivation, maintenance of ground cover and improved trafficability) is also being initiated, they can be combined as contoured, permanent beds. It is well recognised that these practices have a very large impact on reducing sediment generation and transport under high rainfall conditions.

No data is available on the extent of contouring in the banana industry as no data was collected on this issue during Reef Rescue. Hence it is difficult to quantify the benefits. The Johnstone and Russell catchments contain many banana areas with slope in excess of 3%. In the Tully and the Barron catchments slope is less of a problem.

3 & 4. Grassed Inter rows and fallow management
According to Reef Rescue data, 95% of the growers that applied for grants maintain grassed inter rows. Little changed in that figure occurred over the five years of Reef Rescue 1. There is some uncertainty as to how well that claimed area of grassed inter rows is actually managed. Research at South Johnstone initially indicated that B practices (grassed inter rows) were producing more sediment than C practices (bare inter rows). A subsequent year's data where the inter row in the B practice area was renovated has reversed these results. This change of outcome demonstrates that how well inter rows are maintained, is the overriding factor.

Considerable extension work on this practice may be required as many farmers may consider themselves already using best practice when that may not actually be the case. Investment in grassed inter rows during Reef Rescue was low with little demand for funding.

Mixed TSS cropping management practice options

Options are sediment management using:

- Contour banks
- Minimum tillage
- Grassed headlands
- Controlled traffic
- Cover crops

Impact of these options:

Cogle et al. (2011) mention that sediment losses range from 6t/ha with ground cover up to 30t/ha with no cover in mixed cropping lands. Unlike in sugarcane and bananas where the options are more independent of each other, in the mixed cropping farming systems no single one of the options above are going to provide the benefit sought and they should be regarded as a package of practices. Minimum tillage can only reduce the amount of fine sediment being lost but will not completely stop it. Consequently, all of the above options need support from the other practices to be successful. Any one of the above can be overwhelmed by heavy rainfall events hence the need to promote a range of risk management measures.

The farming system on the Tablelands is a high risk system with bare ground in the high risk early wet season time of the year. Cultivation does not generally start until it rains. Most producers use equipment with a horizontal motion for cultivation rather than vertical, promoting a hard pan under the crop. The method of harvesting of both peanuts and potatoes requires a fairly fine tilth with bare areas at the end of each row to allow digger entry providing a source of sediment. Providing a harvester access area and a grassed headland usually uses too much land so a grassed area at the end of a row is not often seen.

Tablelands farmers use a crop rotation system with a range of 3-4 crops depending on the location and individual farmer. For many this system includes a pasture crop for 2-3 years producing hay and/or grass seed. Grass is then followed by a range of other crops which require complete cultivation of the grassed area. A 100% controlled traffic farming system is thus not feasible although controlled traffic equipment is used by many farmers for the row cropping phase of their rotation. Hence, unlike for the sugar cane industry, controlled traffic is not a solution to sediment loss in mixed cropping.

Ground cover on a peanut crop planted in early December is not complete until mid to late February so sediment loss occurs up until March when the canopy is closed and erosion is minimised.

Compared to other industries the solutions to sediment loss on the Tablelands are not easy to achieve.

Dairy TSS management practice options

A high level of ground cover on Tablelands dairy properties, even with poor composition, means that sediment loss from laneways or around cattle aggregation areas like water troughs, does not contribute significant amounts to overall loads. Anecdotal evidence is that installation of troughs nearby encourages cattle away from riparian areas and provides greater benefit in preventing sediment loss from stream banks compared with fencing off those same riparian areas.

3.4.2 Management practice adoption

This section covers the adoption of management practices that has occurred over the last five years in cane, bananas and mixed cropping. Much of the detail is provided in the Basin Profiles for the WQIP.

Sugar cane

There are ~ 1300 sugar cane growers across the Wet Tropics basins. The total area of sugar cane reported by Hateley et al. (2014) is 1,797 km^2 or 179,700 ha. This figure is inconsistent with ABS and mill data (Neil Sing pers. comm.) which estimate the productive area of sugar cane to be ~ 134,000 ha. (Note that this latter figure is used in the 'base case' assessment in the INFFER analysis, see Section 4.2).

Management practice adoption data is available and interpreted through several sources in the region: 1) the Paddock to Reef Program, 2) the Terrain NRM Reef Rescue water quality grants database, and 3) survey data completed by DAFF to inform the economic analysis for sugar cane in the region (Van Grieken et al., 2010; Poggio et al., 2014). Due to variations in the scope and detail of these datasets, the adoption characteristics do vary between the sources, and this variability is currently being rectified through the Paddock to Reef Program with support from the Reef Programme.

When taking into account management practice systems, a large proportion of sugar cane area in the Wet Tropics is currently managed at or below C class practices. Table 3.9 lists the extent of the use of C class practices for row spacing, which is an indicator of the extent of the adoption of new farming systems or controlled traffic. We are therefore using adoption of this practice as a proxy of C class management practice systems in cane. While fertiliser rates would be a better measure of management practice systems, there is insufficient data on rates used by individual farmers compared to available data for row spacing. Note these results are sourced from Reef Rescue data where information is captured for farmers receiving water quality grants. This data covers 86% of the total cane area in the Wet Tropics region, but obviously misses a part of the farming community that is not participating in the water quality grants program. Detailed results from the Reef Rescue database are presented in Sing and Barron (2014). Preliminary results of a 2014 survey of farming practices of a sample of these farmers indicates that a large proportion are below industry standard for controlled traffic (D. Bass Terrain NRM, pers. comm.). It should also be noted that these practices are not necessarily equally distributed within basins.

The average proportion of area in C class practices across the region is estimated to be 63% (Table 3.11; derived from Sing and Barron, 2014). The proportion of C class practice adoption is greatest in the Russell (85%) and Daintree-Mossman (82%) basins, with the Herbert showing the most positive result (only 41% in C class practices). However, this can be misleading as the total area of cane in C class practices in the Herbert basin is the greatest in the region. The proportion estimates are useful for selecting delivery mechanisms within a basin, while the area analysis will inform regional priorities.

Farm size is a good indicator of the likelihood of adoption of better management practices, with a close correlation between larger farms and higher levels of practice (Sing and Barron, 2014). This also correlates with economic analyses which indicate it is more economically viable for larger farms to adopt higher level practices (Smith et al., 2014). The data in Table 3.11 is classified into three main farm sizes: Small (<100ha), Medium (100-200ha) and Large (>200ha). This classification indicates that the Tully-Murray and Daintree-Mossman basins have the greatest proportion of large farms (>200ha). The greatest proportion of small farms (<100ha) are in the Johnstone (26%) and Barron (23%) basins. This data is also useful for informing the choice of delivery mechanisms for management practice improvement in each basin. For example, basins with a high number of small farms will require additional extension effort combined with water quality grants, while large farms should benefit from targeted extension and training activities alone, due to better economic viability of improved practice adoption.

Table 3.11. Current adoption of C and D class practices in cane in the Wet Tropics region, and average farm size as at 2013. Source: Sing and Barron (2014). The shading represents the highest (dark green) and second highest (light green) rankings in the region.

Basin	Proportion managed at C or D class practice (based on ha)* %	Total area (ha) of C or D class practices	% of area with small farms <101ha		% of area with medium farms 101ha-200ha		% of area with large farms >200ha	
			% of area at each farm size	% of farmers	% of area at each farm size	% of farmers	% of area at each farm size	% of farmers
Daintree-Mossman	82%	4,715	13	40	36	37	50.5	24
Barron	53%	2,107	23	46	33	35	44	20
Mulgrave	57%	3,985	18	46	33	31	49	22
Russell	85%	4,596						
Johnstone	66%	10,341	26	62	25	23	48	15
Tully-Murray	60%	15,984	8	36	15	23	77	41
Herbert	41%	20,864	13	38	28	35	59	28

*Note these areas of adoption are sourced from Reef Rescue data for the Wet Tropics region which only covers 86% of the total regional sugar cane area.

Based on the combined data in Table 3.11, from a regional perspective it could be concluded that the Tully-Murray basins would be a beneficial area to target for the adoption of new farming systems due to the high proportion of large farms, and the relatively large area of cane currently estimated to be in C class practice. Further prioritisations would need to take into account the outcomes of the relative risk assessment and the necessary pollutant load reductions required to meet the targets. This is discussed in Section 8.

Bananas

There are ~ 200-210 banana growers across the Wet Tropics basins. The total area of bananas reported by Hateley et al. (2014) is 156 km^2 or 15,600 ha.

Based on management practice adoption data reported in the Paddock to Reef Program, it is currently estimated that for practices related to DIN reduction (rate, timing and placement of fertiliser) the current adoption of management practice classes by area is 1,207 ha (this is only using data from 2009-13 as practice data was not collected in 2008). This equates to the following areas in each practice class for fertiliser application: 559 ha at A, 608 ha at B, 40 ha at C.

Mixed cropping

There are ~ 65 mixed cropping growers across the Wet Tropics basins. The total area of mixed cropping reported by Hateley et al. (2014) is 150 km^2 or 15,000 ha.

Based on management practice adoption data reported in the Paddock to Reef Program, it is currently estimated that for practices related to TSS reduction the current adoption of management practice classes by area is 6,883ha. Change to GPS controlled traffic, which is an indicator of a move to whole farming system has the following areas in each practice class: 4,651 ha at A, 2,113 ha at B and 119 ha at C.

Grazing (dryland)

There are ~ 30 graziers across the Wet Tropics basins. The total area of dryland grazing reported by Hateley et al. (2014) is 6,950km^2 or 695,000 ha.

Dairy

There are ~ 59 dairy farmers across the Wet Tropics basins. The total area of dairy farms reported by Hateley (2014) is 300 km^2 or 30,000 ha.

3.4.3 Improving urban and other land use management practices

Urban Water Quality Management

The total area of urban land uses in the Wet Tropics region is 314 km^2 or 31,400 ha (Hateley et al., 2014).

There are eight Local Councils in the Wet Tropics NRM region, including two Indigenous Shire Councils. The Cairns Regional Council is the largest in respect to population size (~147,000) with Cairns being the region's largest city. With the three existing WQIPs in the Wet Tropics both the Tully – Murray and the Douglas content regarding urban issues were low, while the Barron – Trinity Inlet WQIP had a medium level of urban content.

The Local Government in the region has an effective collective mechanism to provide synergies across the region. This mechanism is the Far North Queensland Regional Organisation of Councils (FNQROC). FNQROC incorporates all Councils in the Wet Tropics and others outside the region, providing a number of services, including the provision of a Development Manual utilised by Councils[19]. This manual provides a tool for developers and Councils to undertake practices suitable to Local Government standards, which in turn must meet State statutory obligations including the *Environmental Protection (Water) Policy 2009* and State Planning Policy (July 2014) (SPP) (incorporating the State Interest – water quality)[20]. This organisation also has an important role in progressing Local Government planning aspirations. Terrain maintains a strong partnership with FNQROC, particularly alignment with NRM planning and on ground activities, including the development of spatial tools for both the NRM Plan and the WQIP.

An important link with other GBR regions is the Reef Urban Stormwater Management Improvement Group (RUSMIG) of which Terrain NRM and Far North Queensland Regional Organisation of Councils (FNQROC) are members. This group comprises membership from Local Government with large urban areas in the GBR catchment (Cairns, Townsville, Mackay, Rockhampton, Gladstone and Bundaberg), NRM Groups, GBRMPA, LGAQ and EHP. The core objective of RUSMIG is to improve total water cycle and stormwater management and water quality outcomes associated with urban activities. Under the Australian Government Reef Programme funded project "*Collaboration to the Rescue: Better Reef Water Quality through smart urban water management*", in partnership with Water by Design (Healthy Waterways), a range of products (Table 3.12) were developed and are accessible to Local Governments along the GBR catchment and the general public through the Water by Design website (http://waterbydesign.com.au/).

Terrain NRM maintains a close partnership with both individual local councils and FNQROC. The tools developed by Water by Design and RUSMIG through the urban ***Collaboration to the rescue*** project are designed to increase the capacity of local government and to inform NRM groups about urban water quality issues and the potential for collaborative actions with local government. The principal role of Terrain NRM is to maintain dialogue, support Council's initiatives to improve their capacity to manage urban stormwater and monitor progress.

[19] http://www.fnqroc.qld.gov.au/regional-programs/regional-development-manual.html

[20] http://www.statedevelopment.qld.gov.au/resources/policy/state-planning/state-planning-policy-jul-2014.pdf

Table 3.12. *Collaboration to the Rescue* project product list (2014).

1. Erosion and Sediment Control self-assessment auditing tool pilot

Partner with one local government to test the application of the Erosion and Sediment Control self-assessment auditing tool developed by Healthy Waterways' Integrated Urban Water Scientific Expert Panel. The draft tool is designed to assist local government assess whether their activities to manage Erosion and Sediment Control are effective and identify what they can do to improve compliance.

2. Erosion and Sediment Control 'Business Case'

This project aims to:

- bring together existing information on impact, costs and benefits and to generate new information to build a sound knowledge base that practitioners can draw on when seeking to engage and influence stakeholders to substantially improve ESC;
- provide a rational argument to show why effective Erosion and Sediment Control compliance is required.

3. Water Sensitive Urban Design capacity increase

Conduct workshops with up to six local governments to facilitate self-assessments of their organisations' capacity for Water Sensitive Urban Design and potential management strategies that they could undertake to drive Water Sensitive Urban Design.

4. Bioretention design for GBR catchments

Prepare guidance on bioretention design that is relevant to the Reef catchments through updating the Water by Design Bioretention Design Guideline for better applicability to Reef catchments.

5. Scoping of broader Water Sensitive Urban Design (WSUD) outcomes –' Living Waterways'

Prepare guidance on how broader outcomes, related to factors such as amenity, riparian revegetation and open space integration, can be achieved in conjunction with water quality outcomes through planning and assessment processes i.e. scope a broader set of WSUD outcomes and how to assess projects against these broader outcomes.

6. Stormwater management offsets discussion paper

Prepare guidance on how local governments can establish and implement stormwater management offsets without compromising water quality or ecosystem health

7. Water Quality Improvement Plan support

Provide support to integrate urban matters into Water Quality Improvement Plans (WQIP)

8. Natural Channel Design and Maintenance guidance scoping

Undertake scoping to:

- Understand what resources for Natural Channel Design currently exist;
- What guidance is needed;

Draft a brief to prepare a guidance resource.

9. Bioretention training

Update the current Water by Design bioretention training course and deliver up to five training sessions (to be undertaken once the bioretention design guidance is completed).

10. Construction and Establishment of Vegetated Stormwater Assets training

Deliver up to five sessions of the Water by Design Construction and Establishment of Vegetated Stormwater Assets training course.

11. Erosion and Sediment Control capacity increase

Deliver up to six regional workshops with local government (sediment and erosion control) officers to improve their ability to apply Erosion and Sediment Control measures within local government projects and/or to undertake compliance activities on development sites.

12. Commence the development of a ABCD practice framework as developed for the Agricultural sector

As with the rural land use ABCD classification the urban ABCD management practice classification system is designed as a mechanism to compare and rate specific management practices and the potential impacts of those management practices on waterway health. The underlying assumption is that different standards of management practice result in different levels of water quality pollutants leaving urban areas in stormwater runoff. Theoretically and practically if we improve management practice standards then we can reduce the amount of water quality pollutants emanating from urban land uses.

Management of urban water quality can firstly be separated into issues associated with point sources and diffuse sources (Figure 3.14). Point source pollutants are reasonably easy to address in terms of management actions as the issue is relatively well defined and management options are also well known such as Wastewater Treatment Plant upgrades. As with most infrastructure based solutions one of the main considerations is cost.

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

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

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

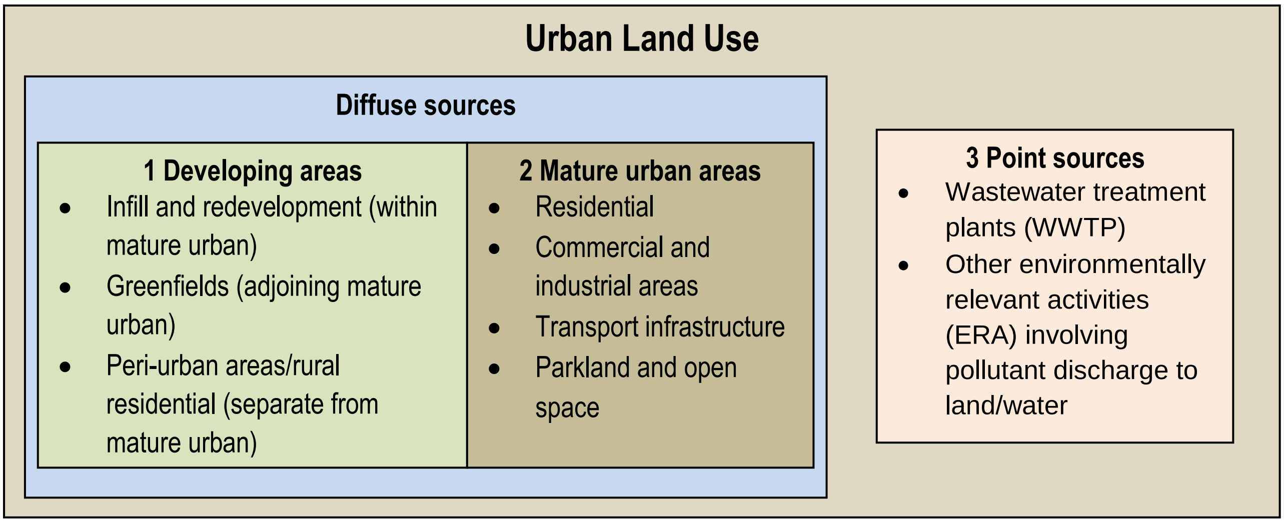


Figure 3.14. Components in consideration for water quality and other environmental outcomes in the urban setting. Source: Gunn (2014).

The primary water quality pollutants for developing urban areas and mature urban areas are different and as a consequence the management strategies and priority management actions for each land use are also different. Diffuse source water quality improvement for urban land use is achieved through a combination of regulatory provisions, voluntary initiatives and the adoption of a flexible, integrated catchment management approach to total water cycle management (Gunn, 2014).

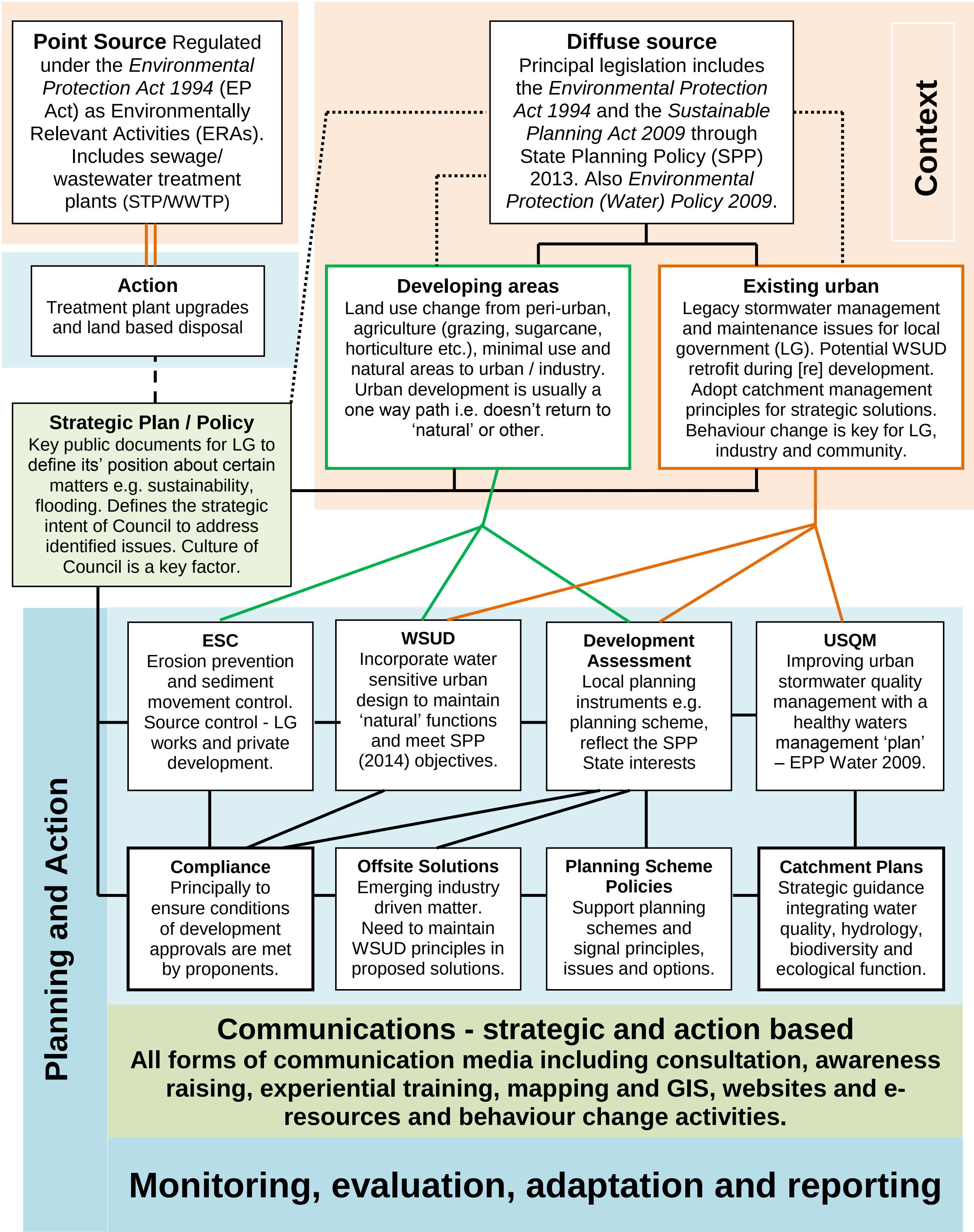
Legislation – Urban Context

The majority (more than 80%) of urban development in regional Queensland occurs within 20 kilometres of the coast. This concentrated growth demographic, population increase in general and 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 including rapidly expanding urban areas and associated infrastructure (Gunn, 2014).

Queensland legislation (Acts and key subordinate legislative instruments) relevant to coastal development and/or water quality management is listed below:

- *Environmental Protection Act 1994*
- *Environmental Protection (Water) Policy 2009*
- *Sustainable Planning Act 2009*
- *State Planning Policy (December 2014)* (SPP) (incorporating the (incorporating the State Interest – water quality))
- *Coastal Protection and Management Act 1995*
- *Fisheries Act 1994*
- *Aboriginal Cultural Heritage Act 2003*
- *Nature Conservation Act 1992*
- *Vegetation Management Act 1999*
- *Water Act 2000*
- *Marine Parks Act 2004*
- *State Development and Public Works Organisation Act 1971*
- *Land Act 1994*
- *River Improvement Trust Act 1940*

There are a number of different pathways which need consideration when a key objective is good water quality outcomes. Figure 3.15 provides the pathway linkages to statutory requirements and the various components of urban land use.



Notes: Urban includes: Residential – commercial –recreation (formal parks, sports grounds and walking/cycling paths) – industrial (includes transport infrastructure) – transport corridors - [environmental infrastructure is] natural areas – waterways – wetlands – connecting corridors– foreshore and estuaries – protected areas. LG is local government.

Figure 3.15. Pathway linkages to statutory requirements and the various components of urban land use. Source: Gunn (2014).

Draft ABCD management practice framework for urban land use

Management practices were originally listed as a set of practices (potentially A/B class) that will influence and improve urban water quality outcomes. A draft set of A, B, C and D practice 'levels' were subsequently defined. It is unlikely that any given organisation or water quality manager is going to fit neatly into a grouped class of practices i.e. be all B class or all C class, so each practice will need to be assessed individually and then the component scores combined in some way (depending on weighting for different practices) to arrive at an overall 'score' for reporting purposes.

More work needs to be done to arrive at a 'final' system that relates all the individual actions to produce a reporting system that is practical and useful for organisations involved in urban stormwater management including the implications for water quality, costs and benefits and the level of improvement required for each practice for each classification. The draft urban ABCD classification tables are included in Appendix 5 for point source and diffuse source including for developing and mature urban areas and public and private sector development.

3.4.4 Restoring ecological function

While it is recognised that restoration of the ecological function of catchment and coastal ecosystems will be of benefit to the water quality in the GBR, this is yet to be quantified. However, there is sufficient understanding to expect that there would be positive effects on water quality condition from undertaking catchment restoration activities. This is discussed further in Chapter 5 - Strategy 2 - Restoring catchment waterways and ecological function in the Wet Tropics basins.These management options are consolidated into a summary of management actions to focus on in the WQIP in Section 8.1 (Table 8.1).

4. Analysis of options for achieving the pollutant reduction targets

Modelling of land-use adoption scenarios across the entire GBR has shown that complete adoption of industry best management practices in grazing and sugar cane may be sufficient to meet the Reef Plan targets for PSII herbicides, but are well below the proposed reductions for TSS, particulate nutrients, and DIN (Thorburn and Wilkinson, 2013; Waters et al., 2013).

4.1 Progress to date: Paddock to Reef reporting

In the Wet Tropics region, pollutant load modelling results for Report Card 2013 indicate that there has been 'very poor' to 'very good' progress towards meeting the Reef Plan targets (Figure 4.1; Hateley et al., 2014).

- TSS loads were reduced by 12.5% ('very good' progress) from the anthropogenic baseline load. Of the 12.5%, the major reduction was from streambank erosion (50%) mostly due to riparian fencing, followed by improvements in sugar cane practices (43%).
- Whilst there was 'poor' progress towards reducing the Wet Tropics DIN anthropogenic baseline load, investments in sugar cane resulted in a 12.7% reduction in the DIN load. Once all the changes had been taken into account, there were net decreases in area of 18.4% out of the D management system and 14.3% out of the C management system. There was a net increase in area of 25.4% into B and 7.4% move into A. Most system changes were stepwise, so for example C to B, but in some cases, there was a two-step system change from D to B. The biggest increase in area of a management system change was into B practices, attributed to the adoption of the 'Six Easy Steps' nutrient management program. However, it is not known whether the full suite of actions of the program is being adopted by growers and this has implications for nutrient losses. It is evident that adoption of the full program requires further extension efforts and is partially being addressed through the requirement to prepare Nutrient Management Plans to be eligible for Reef Programme water quality grants in the region and the new Terrain sugar cane Training and Extension program.
- The PSII herbicide reduction in the anthropogenic baseline load was the highest out of all constituents at 26% ('moderate' progress) with the reductions attributed to investment in sugar cane. Once all the changes had been taken into account, there was a net decrease in area of 4.7% out of the D management system, 28.8% out of the C management system and there was a net increase in area of 30.6% into B and 2.9% move into A. Most of the change was into B management system, which includes practices relating to the selection of herbicide products with a reduction in the reliance on residual herbicides towards knockdowns for weed control.

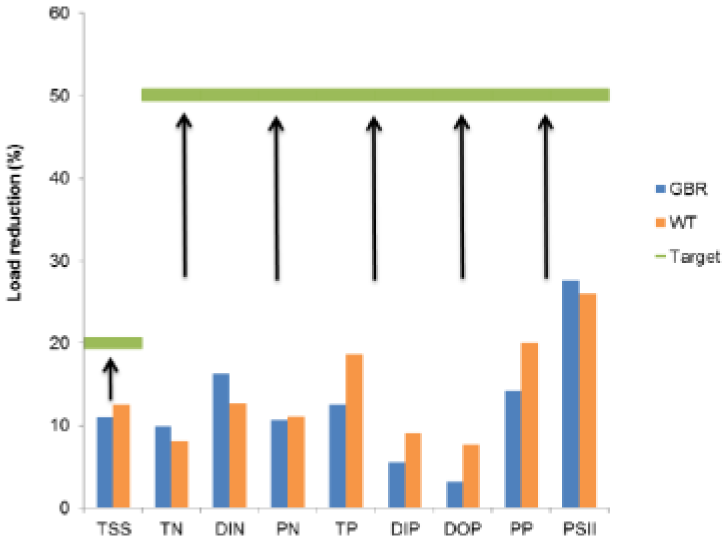


Figure 4.1. Modelled results of Wet Tropics and GBR pollutant load reductions for individual reporting in the Report Card 2013. Source: Hateley et al. (2014).

4.2 Analysis of options for meeting pollutant load reductions in sugar cane

There are multiple factors that influence the ability to meet the proposed pollutant load reductions, and a transparent process is required to combine and assess this information so that informed management recommendations can be developed. To conduct this analysis for sugar cane in the Wet Tropics region, the INFFER (Investment Framework for Environmental Resources) framework has been adopted. The analysis involved participation from a range of technical experts and stakeholders and the use of expert knowledge in workshops. There is insufficient detailed information at this time to conduct the analysis for other land uses in the region. The original scope included analysis of options for the banana industry in the region as well but it was concluded that there was insufficient data, particularly with regard to economics but also across a range of management practices, to complete the assessment. However, it is recommended that this analysis is pursued as new information becomes available for the benefits and costs of banana management practices over the next 2 to 5 years. The key pollutants of concern in the region are DIN and PSII herbicides, a majority of these pollutants are generated from sugar cane land use, providing a sound basis to the scope of this analysis for the WQIP.

4.2.1 The INFFER framework

INFFER uses the principles of benefit: cost analysis to undertake integrated assessments of projects that aim to achieve environmental outcomes. The framework can use whatever information is available including formal economic, social and biophysical studies as well as expert judgment. Detailed information on INFFER is available at www.inffer.com.au

Undertaking the analysis requires collection of the following information:

- Clear **identification** of the environmental asset, including spatial location and extent.
- The **significance** or value of the asset.
- The **threats** that are affecting or are likely to affect the environmental asset.
- Specific, measurable, time-bound **goals**.
- **Works and actions** that are proposed to be undertaken to achieve the goals.
- The **time lag** between undertaking the project and the generation of benefits.
- The **future degree of environmental damage** with and without the proposed works and actions.
- The **risk of technical failure** of the project.
- **Positive and negative spin-offs** from the project (e.g. impacts on other environmental assets).
- The **likely extent of adoption** by private landholders of the works and actions that would be required to achieve the stated goals.

The variables that feed into calculation of the **Benefit: Cost Ratio** (Pannell, 2012) are mostly specified as proportions, and are included in the Index multiplicatively.

$$BCR = \frac{V \times W \times A \times F \times B \times P \times G \times DF \times 20}{C + PV\,(M + E) \times G}$$

Within this approach, there is no need to provide weights for each variable (as one would do in a Multi-Criteria Analysis).

The variables that feed into calculation of the Benefit: Cost Ratio are:

- V = value of the asset
- W = multiplier for impact of works
- F = multiplier for technical feasibility risk
- A = multiplier for adoption
- B = multiplier for adverse adoption
- P = multiplier for socio-political risk
- G = multiplier for long-term funding risk
- DFB = discount factor function for benefits, which depends on L
- L = lag until benefits occur (years)
- C = short-term cost of project
- PV = present value function
- M = annual cost of maintaining outcomes from the project in the longer term.
- E = compliance costs for private citizens, if the project involves enforcement of regulations. The methods and processes adopted and input data for the each of these parameters in the Wet Tropics sugar cane assessment are described in further detail in Park and Roberts (2014a,b).The key information is summarised below.

4.2.2 Management scenarios

The base case for the INFFER analysis was framed against the following Ecologically Relevant Targets (ERTs):

That by 2030 there will be a:

- 70% reduction (or higher) in toxic PSII loads (predominately influenced by the diuron load) to achieve the guideline values.
- 80% reduction in the anthropogenic DIN load.

Three project scenarios were considered in the INFFER assessment for sugar cane in the Wet Tropics:

- 100% of sugar cane land is under A practice after 5 years.
- 50% of sugar cane land is under A practice and 50% is under B practice after 5 years.
- 100% of sugar cane land is under B practice after 5 years (more likely medium term target).

These are the scenarios where estimates of pollutant load reductions are available through the Source Catchments modelling (Hateley et al., 2014). A number of basin specific combinations of these scenarios were also tested.

4.2.3 Asset value and threats

In this assessment, the asset being assessed is the GBR. A credible numerical value was established which provides a point of reference for assessing the benefits and impacts of the proposed project. This was based on environmental, social and economic values and was informed by the regional evaluation conducted by Thomas and Brodie (2014) and additional expert opinion obtained through the workshop processes. Non-market values were also considered in a national context. The results suggest that the Wet Tropics region has the largest market value in the GBR, driven to a large extent by its large reef-specific tourism industry, with an estimated current annual value of A$140m (~37% of total GBR reef-specific tourism value). Commercial fishing in the region contributes approximately A$10m (~9% of total commercial fishing value) and recreation A$30m (~24% of total recreation value) to the market value of the GBR. A range of asset values were used in the assessment as a sensitivity test to deriving the asset value.

As identified in Section 2.3, a range of threats, in addition to pollutant run-off from agriculture, continue to impact on the health of the GBR in the Wet Tropics region. While the focus of the INFFER analysis is on management practice interventions in sugar cane to reduce pollutant loads, other threats will continue to operate into the future. For this reason it is important to understand the relative importance of this threat relative to other threats, such as climate change, on the asset. As the targets (Section 3.3) are set with a 20-year time frame, we considered the same time frame in estimating the relative contribution of terrestrial run-off to loss of asset value over the next 20 years. The key threats considered in the INFFER analysis are summarised in Table 4.1 and were derived from the workshop process.

Table 4.1. Relative impact of key threats to the Great Barrier Reef asset based on the current situation. Estimates were derived through expert elicitation in a workshop situation.

Threat	Level of impact	% of total effect on asset
Terrestrial run-off	Very High	50
Extreme events	High	30
Coastal development and urban run-off	Low/Medium	10
Increasing temperature and ocean acidification	Low	5
Others – fishing, recreation etc.	Low	5
TOTAL		100

It should also be noted that within the context of a WQIP, threats such as extreme events cannot be managed per se as the cause of the threat is exogenous to any potential management activity. Rather, the role of the WQIP investment is to focus on risks that can actually be mitigated through a WQIP investment process.

4.2.4 Effectiveness of the alternative management scenarios

For the assessment it is assumed that actions in the sugar cane industry (but not other land uses), will contribute to the achievement of the targets. While efforts were made to obtain economic information for the banana industry this was not available within the timeframe of delivering this WQIP. Additionally, the modelled nutrient and pesticide reductions (Hateley et al., 2014), applied in this analysis are based on sugar cane alone, which is understood to be the most significant contributor to agricultural pollutant run-off. It is also the crop with the greatest extent in the Wet Tropics. Data on other industries is a major information gap that should be addressed over the life of this WQIP.

For the works detailed below it is assumed that landholders will be moving to A class for each practice. Estimates of load reductions and costs are therefore based on all landholders shifting to the combined suite of A class practices. Additional scenarios (for example 50%A: 50%B and all B) were also compared in terms of relative cost-effectiveness against this all A 'base case'.

The actions relevant to reducing pollutant loads from sugar cane are based on the ABCD Framework (Round 6, Cane Practice Tables, Cane Industry Working Group). As described in Section 3.2 and Appendix 4, the following on-ground actions are required to reduce the loss of TSS, DIN and PSII herbicides from sugar cane:

Cn3.0 Rate of fertiliser use, Cn4.0 Timing of fertiliser application, Cn5.0 Placement of fertiliser

Cp12.0 Herbicide application timing, Cp32.0 Residual herbicide use in plant crops , Cp33.0 Residual herbicide use in ratoons

Cn16.0 Row spacing, Cn17.0 Cultivation prior to planting, Cn21.0 Riparian management, Cssd22.0, Csdp 22 and Cs 40.0 Drains and headland management

Whilst there are a number of other practices identified in the ABCD Management Frameworks for sugar cane (e.g. soil testing), the assessment focused on those practices that make a material difference to reducing constituent loads. In doing so it is acknowledged that practices such as soil testing are a precursor to on-ground works, such as reducing nutrient application. As such, this is captured in the economic analysis when considering the profitability and costs of adopting new practices.

The assessment of practice effectiveness is based on estimates which were derived from expert opinion and review of the literature (see Sing and Barron, 2014). The major contribution of DIN from sugar cane areas results from the following practices: fertiliser (N) application, including the amount used and timing, and to a lesser extent its placement. It is estimated that row spacing and cultivation prior to planting contribute to a low loss of DIN (~5%). It is estimated that the major contribution of PSII herbicides from sugar cane areas results from the timing of herbicide application (60%), followed by residual use in plant crops and ratoons (30%) and row spacing (10%) (Neil Sing, pers. comm.).

To estimate load reductions from the implementation of works, it is necessary to estimate the proportion of the current DIN load that is associated with sugar cane in the region. Hateley et al. (2014) notes that 41% of the total Wet Tropics DIN load is contributed from sugar cane, and 96% of the PSII herbicide load. Modelling estimates indicate that 83% of the anthropogenic DIN load is derived from sugar cane (74%), banana (10%) with 10% from urban land uses. Additional scenarios were run that modelled an 'All A' scenario through to an 'All D' scenario for DIN and PSIIs for sugar cane (Hateley et al., 2014). The results from the Report Card 2013 were included to demonstrate how progress related to the other hypothetical scenarios. Under an 'All A' scenario, DIN was expected to be reduced by up to 28% from the anthropogenic baseline (Figure 4.2). The largest stepwise shift (excluding 2012-2013) was a shift from the anthropogenic baseline to an 'All B' scenario. A reduction of up to 95% is possible under an 'All A' scenario for PSIIs (Figure 4.3). The larger jump from the anthropogenic baseline to an 'All B' scenario for PSII herbicides compared to DIN reflects the larger proportion of C and D management in the PSII anthropogenic baseline load.

However, one of the limitations of the modelling was that management changes only affected the load derived from the quick-flow (event flow) component of the total flow which may have resulted in under estimates of the predicted load reductions. This limitation only affected the magnitude of modelled reductions of dissolved nutrients such as DIN, because fine sediment and PSII herbicides have a very small slow-flow load or no slow-flow load in the current model structure. For sugar cane and grazing, the proportion of slow-flow was estimated to be approximately 41% of the total modelled flow. In order to make modelled export loads of DIN more equitable with validation data, the Wet Tropics region had a significant proportion of DIN slow-flow load, which resulted in that portion of the load remaining unchanged in all scenarios. This is due to the lack of scientific knowledge to confidently represent the interaction of groundwater with streams, and the associated DIN transfer that may (or may not) occur. As the model structure improves and more data becomes available regarding this, the representation will be made. Therefore, it is expected that the load reductions in these scenarios are an underestimate of the load reductions likely to be achieved with a shift to all A or 50A:50B practices, but this is yet to be tested.

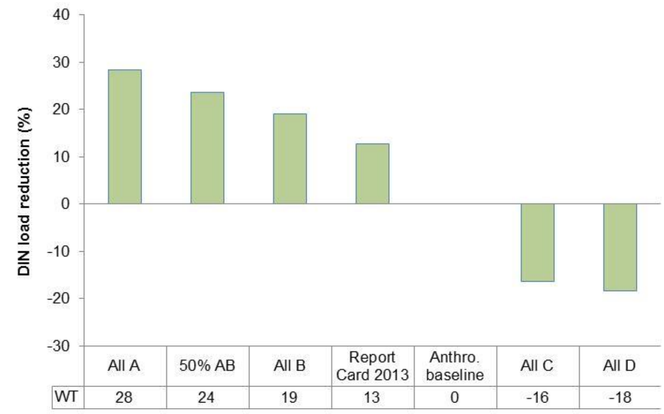


Figure 4.2. DIN load reductions from additional management practice scenarios. Source: Hateley et al. (2014).

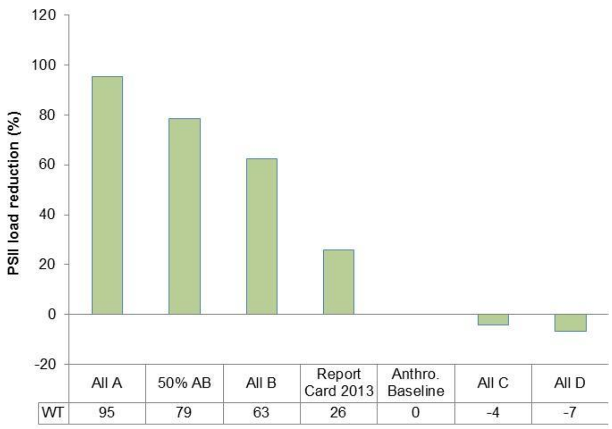


Figure 4.3. PSII load reductions from additional management practice scenarios. Source: Hateley et al. (2014).

Time lags are also considered in the assessment, that is, how long will it take for the majority of benefits for the asset, from adoption of improved practices in sugar cane, to be realised. An overall time lag of fifteen years was estimated for this analysis. In general, the time between the proposed practice shift (e.g. reduction in applied rate of fertiliser) and constituent transfer to the receiving waters is short, certainly less than 1 year. For DIN, the relationship between load reduction and improved asset condition is complex and imperfectly understood. The initiation of Crown of Thorns Starfish (COTS) outbreaks are linked to elevated levels of DIN and the predicted lag time for improvement is estimated at 12-15 years due to the cyclical nature of the outbreaks. For other DIN related effects such as increased susceptibility to bleaching, interactions between macroalgae and coral, a lag time of approximately 10 years is estimated for the reversal of deleterious impacts. Overall it was estimated (through the Project Assessment Form development workshop) that time lags for DIN reduction and asset recovery would be greater than 10 years for coral reefs. For seagrass the recovery phase is potentially shorter, estimated at 3-5 years, assuming adequate light availability. Interactions between DIN and sediment loads (affecting turbidity) are therefore especially important for seagrasses. For herbicides, the timeframes are potentially much shorter and reductions and responses could be measured within the same year.

There is some uncertainty with prediction of this variable; therefore a range of 10 to 20 years was used to explore the sensitivity of the assessment to optimistic and pessimistic views of ecological responses to practice change.

This information is used in the INFFER assessment to estimate the likely impact of the proposed works on the GBR (the asset) based on the following assumptions:

1. The threat from pollutant run-off is estimated to be ~ 50% of the overall threat (but a greater proportion of the manageable threat).
2. Other threats, for example coastal development and climate change, are not addressed and will continue to impact on the asset over the next 20 years.
3. That land uses other than sugar cane and bananas also contribute to pollutant run-off. Sugar cane and bananas account for ~ 33% of the TSS load, 50% of the total DIN load, 83% of the anthropogenic DIN load and 96% of the PSII herbicide load.
4. That the overall impact (e.g. shift to all A practice) of actions in sugar cane and bananas deals with ~ 50% of the combined pollutant contribution from all land uses.

Other factors taken into account are the risk of technical failure of the project. The consensus of discussion at the Project Assessment Form (PAF) development workshop was that there was a moderate risk of technical failure. This was attributed to:

- effects of climate variability
- the proportion of area over which you can achieve the practice
- It was suggested that the risk of failure for actions relating to DIN was ~ 35%, while that for PSII herbicides is slightly less.

Following the workshop further information was provided by Neil Sing, regarding the likely risk of failure for the key practices related to pollutant load reduction for sugar cane.

- DIN - fertiliser rate (Low), timing of fertiliser application (Moderate), fertiliser placement (High)
- PSII herbicides - timing of application (Low), Residual use in planted cane (Moderate) and ratoons (Low)

It is suspected that this assessment may be optimistic, especially given that in many cases A class practices are commercially unproven and have yet to be adopted at significant scale across the Wet Tropics. Thorburn et al. (2013) provide a detailed discussion of links between management practices (for DIN, TSS/fine sediments and PSII herbicides), and water quality outcomes, including discussion of uncertainty associated with relationships between practice shifts and estimated load reductions.

4.2.5 Current adoption of management practices

As described in Section 3.4.3, current adoption of management practices is critical in assessing the likelihood of meeting the pollutant load reduction targets. For this analysis, adoption data for specific practices was derived using stylised farm scenarios within the various sugar cane growing districts. These farm scenarios were developed through consultation with local agronomists, DAFF extension staff and growers within each of the 3 catchments (van Grieken et al., 2013; Poggio et al., 2014). It was estimated that:

- For practices related to DIN reduction (rate, timing and placement of fertiliser) the estimated spread was A (8%), B (20%), C (70%) and D (2%). This equates to the following areas in each practice class: A - 10,720 ha, B - 26,800 ha, C - 93,800 ha and D - 2,680 ha.
- With respect to PSII herbicides the estimated spread was A (5%), B (20%), C (65%) and D (10%). This equates to the following areas in each practice class: A - 6,700 ha, B - 27,000 ha, C - 87,000 ha and D - 13,000 ha.

Accordingly, the following practice change transitions were assessed:

- For DIN: C to A - 20,000 ha and B to A - 94,000 ha.

- For PSII herbicides: D to A - 13,000 ha, C to A - 87,000 ha and B to A - 27,000 ha.

4.2.6 Costs and implications of achieving pollutant reduction targets

A detailed economic analysis has been undertaken by Marcus Smith, QDAFF, to underpin the development of estimated costs of management practice change for the WQIP. The assessment is based on current areas in each of the ABCD practices classes and farm economic data collected through the Paddock to Reef Program and Reef Rescue R&D projects (Poggio et al., 2014; van Grieken et al., 2010; 2014). The full report ((Park and Roberts, 2014a) captures the data and assumptions used for the assessment. Additional basin scenarios were also explored and reported (Park and Roberts, 2014b).

Based on outputs generated from the model, the following assumptions were made in relation to the profitability or costs associated with practice shifts:

1. A discount rate of 6% with an investment period of 10 years was used.
2. The total cost of all current allocations of farming area shifting to A class practices was estimated by weighting the economic results from changing practices by: (1) the current proportion of farming area within each class; and, (2) the current proportion of farming area grouped into representative farm sizes.
3. Based on the current area in each of ABCD practice classes the following practice change transitions are required for DIN: D/C to A - 96,480 ha and B to A - 26,800 ha and for PSII herbicides the following practice change transitions are required: D/C to A - 100,500 ha and B to A - 26,800 ha.
4. Calculations for shifting from D class were not analysed specifically in the reference reports. On this basis, the economic results of practice shifts from D were combined with shifts from C Class. (Those at D practice nutrient management make up 2% of total farming area, while those at D pesticide management make up 10% of total farming area).
5. The investment analysis is based on three average farm sizes, 50 ha, 150 ha and 250 ha.
6. Based on indicative figures for farm size (Sing and Barron, 2014) the investment results for the representative farm sizes were weighted as follows: small farm <100ha (covering 35,987 ha in the Wet Tropics region); medium farm 100-200ha (covering 40,407 ha); and large>200 ha (covering 57,606 ha).

The results indicate a total weighted cost of approximately $3.665M per year to shift to all A class practice for DIN and PSII herbicides in sugar cane in the Wet Tropics over 10 years and almost neutral cost to shift to All B as shifting to these practices is demonstrated to be profitable (Poggio et al., 2014; van Grieken et al., 2010; 2014). The total weighted costs were also calculated for a number of alternative scenarios. The estimates take into account the full cost of practice change such as capital costs of equipment and machinery, input costs (nutrients and chemical), operating costs (including fuel and electricity costs, contractors, soil testing and equipment calibration) and sugar cane returns. Note that the total costings do not take into account current funding available for management practice change in the region.

A number of limitations regarding the economic analysis are listed as follows:

1. The concept of costs and profitability is only analysed at the farm level.
2. The profitability of other sectors within the cane industry may be affected also; e.g. harvesting contractors and millers, as well as agri-businesses linked throughout the local supply chain. The effects from changes to income within these sectors are likely to flow-on into secondary impacts on household consumption within the region.
3. There is substantial variation between farming enterprises, which implies that those practising similar operations may end up with higher or lower gross margins than those that form the basis of the investment analysis.
4. A-Class management is based on practices under research and not thoroughly tested on a commercial scale.

Moving to A-Class management practices is likely to be perceived by growers as representing a greater business risk than moving to B-Class management - growers may require a higher rate of return on investment than 6% to compensate them for assuming relatively greater risk.

4.2.7 Delivery mechanisms suggested by the assessment

The complexity and scale of this project will require a mix of delivery mechanisms. To select appropriate delivery mechanisms for implementation it is important to consider the relative levels of public (external) and private (internal) net benefits from the proposed actions. Depending on relative levels, it may be appropriate to use positive incentives, negative incentives, extension, technology development, or no action. To guide the choice of policy tools relating to private land the Public: Private Benefits Framework (Pannell, 2008) has been used. Under this approach policy mechanisms are grouped into one of five categories:

1. Positive incentives (financial or regulatory instruments to encourage change).
2. Negative incentives (financial or regulatory instruments to inhibit change).
3. Extension (technology transfer, education, communication, demonstrations, support for community network).
4. Technology change (development of improved land management options, such as through strategic research and design (R&D), participatory R&D with landholders, provision of infrastructure to support a new management option).
5. No action.

The framework highlights the importance of targeting funds for environmental programs to selected areas, based on the levels of public and private net benefits. In particular, the framework indicates that mechanisms should be used as follows:

- Positive incentives - where public net benefits are highly positive and private net benefits are close to zero.
- Negative incentives - where public net benefits are highly negative and private net benefits are slightly positive.
- Extension - where public net benefits are highly positive and private net benefits are slightly positive.
- Technology development - where private net benefits are negative (but not too negative) and public net benefits are positive.
- No action - where private net benefits outweigh public net costs, where public and private net benefits are both negative, where private net benefits are sufficiently positive to prompt rapid adoption of environmentally beneficial activities, or where private net costs outweigh public net benefits (provided that technology development is not sufficiently attractive).

The options considered in the INFFER assessment are outlined below.

Extension

To support the adoption of B class practices in sugar cane, which are deemed profitable, a targeted extension program will need to be delivered. Due to the large number of growers and cane enterprises, and heterogeneous nature of the region this program will require adequate ongoing resources. It is estimated that an additional 6-8 FTE extension staff will be required to underpin this program. Recent assessments by DAF indicate that the current effort across the region (May 2015) is approximately 20 FTE involved in BMP delivery, grants delivery, group extension, on farm trials and demonstrations, and provision of technical advice roles with a direct water quality focus (C. Wegscheidl DAF, pers. comm.). These officers are currently employed by a range of organisations including DAF, Productivity Services (Mossman, Mulgrave, Tully and Herbert), Canegrowers and Terrain NRM. This is based on expert opinion with at least 4 FTE considered to be necessary to carry out fairly detailed one-on-one work with individual farmers looking at their farm risk situation. It also assumes that the existing effort still needs to be retained. The greatest potential gains will come from working with larger cane growers, where 170 growers manage 60% of the area across the region (Neil Sing, pers. comm.). There is also the potential to target high risk/pollutant generating areas such as low lying cane land where there is the most scope for improving N use efficiency or reducing N surpluses.

While improvements in farm management practices provide the foundation for pollutant reductions, we also recognise that a number of social and economic factors influence the feasibility and capacity to implement these changes across the region, and these factors must be taken into account in making management decisions. For example, farm size has an important influence on the cost effectiveness of the adoption of improved management practices, with changes typically becoming more profitable for larger farm sizes. An analysis of farm size and adoption of management practices in the region indicates that it is the larger farms that are adopting a higher level of practices (Sing and Barron, 2014). It is therefore important that management options are able to be tailored to be relevant across the region, emphasising the importance of strong industry extension programs.

Incentives

Financial incentives will be required for growers to shift permanently from B to A practice (Sing and Barron, 2014; Marsden Jacob Associates, 2013). The level of these payments is estimated to be in the order of $3.7 million per year over 10 years, and has been incorporated into the overall estimates of costs. Incentive delivery must be supported by ongoing extension. Even though shifting to B practice is shown to be profitable to growers, it is likely that maintenance of a small scale incentive program in priority areas (e.g. in the order of $1-2 million per year) would be beneficial to support broad scale adoption of B class practices in the next 2 to 3 years.

Research and Technology development

A number of A class practices, especially for DIN reduction, are associated with the adoption of new and unproven technologies. While these practices offer potentially significant environmental benefits, the private benefits are presently highly negative. It is recommended that ongoing research and development, including field trials be undertaken to investigate the commercial viability of these practices.

Other options

In 2010, Great Barrier Reef protection measures were included in the Environmental Protection Act 1994 and the Chemical Usage (Agricultural and Veterinary) Control Act 1988 to reduce the impact of agricultural activities (sugarcane growing and cattle grazing) on the quality of water entering the reef, and contribute to achieving the targets outlined in Reef Plan.

The legislation requires cane growers in the Wet Tropics (with cane production areas greater than 70 ha) and cattle graziers (on properties greater than 2000 ha) in the Burdekin catchment to complete an Environmental Risk Management Plan. In addition to this, all cane growers within the Wet Tropics, Burdekin and Mackay Whitsunday catchments are required to calculate and use no more than the optimum amount of nitrogen and phosphorus fertiliser, follow chemical use conditions, and keep records.

In December 2012 the Queensland Government announced agreements with the sugarcane and grazing industries to support the development and implementation of Best Management Practice (BMP) programs to boost agricultural productivity and help protect the Great Barrier Reef. The grazing and cane BMP systems are currently being rolled out and will contribute to achieving water quality targets under Reef Plan, and include accountable reporting of industry performance, underpinned by credible accreditation systems.

The existing reef protection legislation will stay in place as producers transition to industry BMP systems. The Reef protection legislation will be reviewed once the BMP programs take effect.

It should be noted that whilst these regulatory approaches have not been considered in the analysis, they remain relevant to future efforts to protect the GBR. If improvements cannot be made with the mix of policy tools outlined above, that is extension, incentives, and R&D, then other options such as reinstatement of regulatory approaches may need to be considered in cases where adoption of new management practices (e.g. application of new pesticides) is generating harmful environmental outcomes.

More extreme options like land buy-back and land use change were not considered in the assessment due to insufficient availability of information to make appropriate cost estimates, and the potentially high socio- political risk that is likely to be associated with these options at this time.

The socio political risk of the scenarios that were run was assessed as being moderate and takes into account factors such as cooperation of other organisations, capacity for delivery, and social, administrative or political constraints such as support or opposition by local community groups and political resistance. The most significant risk in this project is associated with the proposed shift to A class practice. Currently this option is not supported by the major industry body, Canegrowers, and there is a strong likelihood of resistance, even with the proposed incentive payments partly associated with the economic feasibility of some A class practices but also limitations posed by seasonal climatic conditions. The application of an incentive based solution as proposed, poses additional socio-political risks, including:

- negative reaction from other industries in the Wet Tropics
- perceptions of inequity from other cane growing regions
- implications associated with targeted application of incentives (e.g. towards the larger growers, or highest contributing basins)
- uncertainty related to the design and delivery of the incentive program

The likelihood of long term funding is also important for successful implementation of the project, which is essential for the options presented in this case. The prospects for obtaining long-term funding was judged as possible, given that long-term plans such as the Reef 2050 Long-Term Sustainability Plan and institutional arrangements are in place, but the level of funding required is greater than what has historically been available.

4.2.8 Benefit:Cost Results

The results of the INFFER analysis are summarised in Table 4.2. More detailed explanation is provided in Park and Roberts (2014a).

Table 4.2. Results of the INFFER analysis for sugar cane management projects in the Wet Tropics region, based on Reef Plan targets. Red indicates that Reef Plan targets are not met; green indicates that Reef Plan targets could be met. Source: Park and Roberts, (2014a).

Sugar cane Case – based on 5 years	Annual funding required ($M) in the first 5 years	Benefit: Cost Ratio (BCR)*	Predicted DIN reduction (RP Target 50%)	Predicted PSII reduction (RP Target 60%)
A. All A practice	6.6	0.49	~30%	~95%
B. 50% A: 50% B	5.8	0.54	~24%	~79%
C. All B practice	2.6	1.3	~19%	~63%

Note: A Benefit: Cost Ratio of 1 is cost-neutral, >1 indicates greater benefit than cost and <1 indicates a greater cost than benefit.

The analysis indicates that:

- A shift to A class practices comes at a significant cost to growers (as per the economic analysis undertaken by M. Smith and noted in Section 6.3; refer Park and Roberts, 2014a).
- Annual costs = 'stewardship' payment to adopt and maintain A class practices.
- Shift to all A class practices meets the PSII herbicide targets (both Reef Plan and ecologically relevant targets) but achieves 60% of the Reef Plan DIN target, and less than 50% of the DIN ecologically relevant target.
- Shift to B class practices appears profitable to growers so the costs are largely associated with extension programs to shift farmers from C class practices. The Reef Plan PSII herbicide targets can be met with All B practices, however the load reduction falls well short of the Reef Plan DIN targets let alone the ecologically relevant targets.
- It is assumed that B class practice can be achieved with extension alone, while a shift to A class practices would require a combination of extension plus incentives. However, further discussion following the analysis indicates that continuation of a small scale incentive program in priority areas may be beneficial in the short term to facilitate and maintain grower interest.
- It is assumed that there is a linear relationship between load reductions and ecological response of the GBR which is not necessarily the case due to the effect of other external factors such as pollutant dynamics and other drivers of ecological response.

The results are presented in the context of the Pannell (2008) Public: Private Benefits Framework in Figure 4.4. It indicates that the optimal delivery mechanisms for shifting to All B practices is through extension, and that shifting to All A class practices is not favourable without substantial incentives, as this shift is unprofitable under current conditions (Park and Roberts, 2014a). Given the fact that A class practices are commercially unproven, and appear to be highly unprofitable, they should be the focus of R&D to facilitate future technology change.

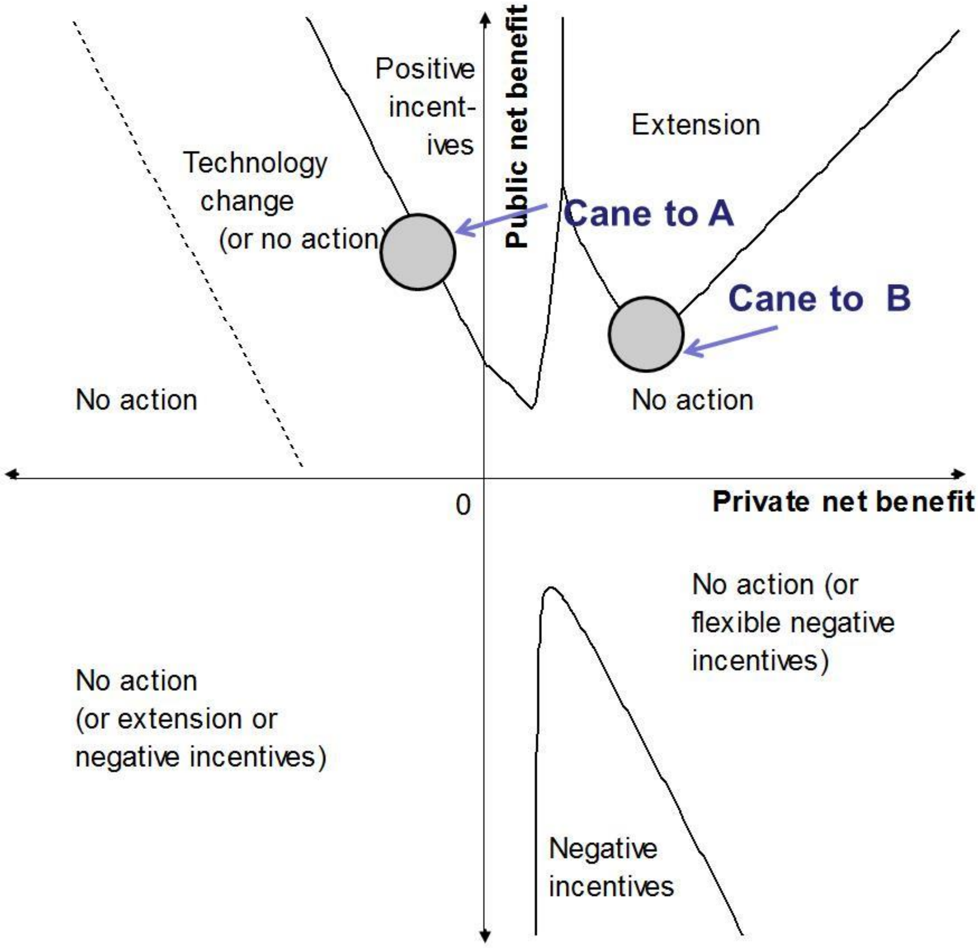


Figure 4.4 Results of the Wet Tropics sugar cane INFFER analysis in the context of the Pannell (2008) Public: Private Benefits Framework.

Exploration of basin-specific scenarios indicates that targeting individual basins would be a more cost effective management option than standardised requirements across the whole region. The scenarios that were tested were based on the basins that were identified to deliver the highest relative risk to the GBR from pollutant loads (Waterhouse et al., 2014): the Russell-Mulgrave, Johnstone, Tully-Murray and Herbert. Information on current loads, modelled load reductions under the three main management scenarios and estimated costs of shifting management practices to each management scenario are presented in Appendix 6.

The results in Table 4.3 indicate that a combination of options may provide the best outcome in terms of pollutant load reduction at least cost. While many of the BCRs are comparatively better than the 'All A class practice' scenario, the greatest load reductions are still the highest BCR in this case. Scenarios M to R show the BCRs for shifting to all B practices in each basin. The most cost effective scenario tested is shifting to All B practices in the Johnstone and then the Tully-Murray basins, however the greatest DIN reductions would be achieved in the Herbert and Russell-Mulgrave basins. Therefore targeting investment in all of these basins is most likely to be beneficial.

These results will be used to provide guidance to investment options and priorities for sugar cane only. While it is recognised that there are limitations in the input data and our understanding of the links between management practice change and water quality outcomes (see Section 10) this is the most comprehensive integration of information available to make investment decisions that are more informed than can be argued previously. Accordingly the results are being used as one of several lines of evidence for the WQIP Implementation Plan, and have been verified using regional expert opinion.

Table 4.3. Results of basin-specific scenario analysis for the Wet Tropics sugar cane INFFER analysis. Source: Park and Roberts (2014b).

Scenario Code	Description – to achieve ERT for DIN with practice change in sugar cane only	DIN reduction (% of anthropogenic load)	BCR	Cost over 5 years ($M)
A	Shift to all A practice across all basins	28	0.49	33.3
B	Shift to 50% A and 50% B practice across all basins	24	0.54	29.1
C	Shift to all B practice across all basins	19	1.3	13
D	Shift to A practice in Johnstone, Tully-Murray and Herbert only	22	0.52	25.4
E	Shift to A practice in the Johnstone and the Tully-Murray only	11	0.62	10.7
F	Shift to A practice in Johnstone and Herbert only	17	0.79	19.4
G	Shift to A practice in the Johnstone only	5	0.90	4.7
H	Shift to A practice in the Herbert only	11	0.57	14.7
I	Shift to all A in the priority basins: Russell-Mulgrave, Johnstone, Tully-Murray and Herbert	26	0.49	29.9
J	Shift to all B in the priority basins: Russell-Mulgrave, Johnstone, Tully-Murray and Herbert	15	1.90	11.7
K	Shift to all A in the Daintree-Mossman and Barron	2	0.47	3.4
L	Shift to all B in the Daintree-Mossman and Barron	1	0.98	1.3
M	Shift to all B in the Daintree-Mossman	17	1.20	0.3
N	Shift to all B in the Barron	4	0.30	0.3
O	Shift to all B in the Russell-Mulgrave	20	0.80	0.9
P	Shift to all B in the Johnstone	9	3.10	0.9
Q	Shift to all B in the Tully-Murray	11	1.27	1.2
R	Shift to all B in the Herbert	58	0.22	2.9

4.2.9 Implications of results and options within the GBR context

Based on these results for sugar cane in the Wet Tropics region, it is evident that it will be challenging to meet the 2018 Reef Plan targets and the longer term ecologically relevant targets by relying on the current suite of agricultural management practices, and alternative measures must be considered. However, there are significant additional factors that need to be considered in reaching this conclusion:

- This analysis is based on cane only and it is unknown what synergies will come from improvement in other industries.
- The analysis is based on current A practice 'being statically applied' for the 20 years. These A class practices will rapidly be recognised as B class practices as they are proven and adopted. It is unknown what significant improvements may be made from future practices that are considered to be A class.
- Restoration of ecological functions in the floodplain and coastal ecosystems will be critical for catchment waterways and to some extent for marine ecosystems however the water quality benefits / load reduction of these restorations to these areas cannot be quantified at this stage. Presently the likely benefits of these restoration activities are yet to be quantified and will be highlighted as a knowledge gap in the WQIP.
- The Wet Tropics landscape is likely to change over the next 20 years. Additional external factors such as agricultural expansion, intensification of agricultural land uses, or increased pressure from coastal development have not been factored into this analysis but are likely to make targets even more difficult to achieve. This is a limitation of the assessment to be considered in future work.

4.3 Analysis of options for reducing pollutant loads from other land uses

At this time there is insufficient data to undertake a detailed economic analysis of the options for reducing pollutant loads from other land uses which would be comparable to the assessment completed for sugar cane using INFFER. However, Marsden Jacob and Associates (2013) have undertaken an assessment of the relative costs of pollutant abatement options for a number of land uses, as shown in Table 4.4.

Table 4.4. Relative costs of water pollution abatement - nitrogen. Source: Marsden Jacob Associates (2013).

Source	Approximate costs ($/kg/annum)	Comments
Rural diffuse –sugar cane BMPs	-31+38	Significant scope for reductions and enhancing industry commercial outcomes.
Urban diffuse - WSUD	360-450	Limited scope to contribute material reductions in loads.
Point sources - WWTPs	76-200	Implementation will form part of infrastructure provision for regional growth

This variability in abatement costs has a number of implications for planning, policy and program delivery for WQIPs in the Wet Tropics including:

- focussing investment on rural diffuse sources that represent the major sources of nutrient and pesticide emission;
- for some loads such as cane, pollution abatement can actually deliver commercial gains to the farmer (i.e. a win-win situation). Policies need to be designed to underpin commercially viable practice change to maximise returns for public investment in pollution abatement activities;
- there is variation in abatement costs for the same pollution type between sectors and land use categories. This raises the option to exploit market-like approaches to ensure pollution abatement objectives can be met at the lowest cost to society. This is particularly the case in the Barron where water quality offsets may be a possible efficient policy mechanism.

Marsden Jacob Associates (2013) also conducted an analysis of relative benefits of investing in various pollution abatement options.

Sugar cane: In agreement with the INFFER assessment, the analysis showed that there are likely to be significant and sufficient private financial gains for most producers to move to current best practice (B class). Given these potential private gains, interventions should be targeted at overcoming impediments to changed practice – for example, information and education, actions to underpin the risk of practice change (such as insurance-like approaches for example, through initiatives such as the Reef Trust), and action to overcome problems in accessing capital. In the longer-term, the public funding of these approaches should largely be limited to program design and delivery as any investments in on-ground change would be ultimately financed by producers themselves.

Dryland Grazing: Dryland grazing occupies just over half of the area of the Herbert basin, with limited (dryland) grazing in other basins in the Wet Tropics region. The available information indicates that there is likely to be more potential gains in focusing on sugar and horticulture growers to reduce loads, as opportunities in grazing may be limited. The high level of ground cover in wetter areas means that water quality issues associated with dairying are relatively minor.

Urban diffuse: Actions in new developments have the potential to reduce regional TSS loads by up to 3% after 10 years, at a cost of around $2.0-2.4 million. Estimates of costs of abatement (that include both capital and operating expenditures) indicate that urban diffuse actions are significantly less cost effective than rural diffuse actions at reducing pollution loads.

The Marsden Jacob Associates (2013) analysis concluded that the most cost effective options for diffuse source pollution abatement in the Wet Tropics region are associated with extension and training in the sugar cane industry. In other sectors examined, the opportunities to achieve significant load reductions at low costs are limited. It is therefore recommended that any disproportionate focus on those sectors may ultimately reduce the return on the public investment to reduce pollutant loads in the region.

Chapter 4: Strategy 2 - Restoring catchment waterways and ecological function in the Wet Tropics basins

5. Assessing values, threats and management options for catchment waterway health and ecological function

This and other sections of the WQIP provide a framework that aims to protect freshwater and coastal ecosystem health. This Strategy investigates catchment waterway health and provides linkages of the freshwater component of a catchment to the coastal and marine assets.

5.1 Identifying and assessing Environmental Values and targets

As described in Section 1.4, Environmental Values are the qualities of waters that are required for healthy aquatic ecosystems and for the waters to be suitable for community uses. Therefore, EVs support aquatic ecosystems, aquaculture and human consumption of aquatic food, agricultural uses, drinking water, recreational uses, industrial uses and cultural and spiritual values. Each of these uses of waters is protected by adhering to specific state or national water quality guidelines and these assist in determining the water quality objectives that are the basis of a WQIP. Where multiple uses occur, the most stringent guideline is adopted so that all EVs are protected. These include the values and uses as shown in Table 5.1, which are based on the National Water Quality Management Strategy. The WQIP utilises validated data pertaining to the EVs already defined in the region as part of the definition of 'Values' in the prioritisation undertaken for Strategy 2, described in Section 5.2.1). EVs/WQOs were finalised in November 2014 by the Queensland Government and are available from the EHP website.

Table 5.1. Queensland levels of protection and management for waters in Queensland.

DEHP Level of Protection category	DEHP management category	Value Category definition	Management Intent
High Ecological Value	HEV	High ecological value	Maintain natural (effectively unmodified) condition
Slightly Disturbed	HEVa*	High ecological value - achieve	Improve towards HEV (undisturbed) condition
Moderately Disturbed	SDa	Slightly disturbed	Maintain/achieve water quality objectives for moderately disturbed system
Highly Disturbed	MDa	Moderately disturbed	Arrest decline, stabilise and progressively improve over time towards MD

*'achieve', as opposed to 'maintain'

The National Water Quality Management Strategy and EPP (Water) grade aquatic ecosystems using a hierarchical approach according to their condition or level of disturbance. The most pristine and healthy systems are considered to be of High Ecological Value (HEV). These systems are largely unmodified and are often found in national parks, conservation reserves or inaccessible locations.

The *EPP (Water) 2009* recognises four levels of ecosystem condition for which different management intent, or Level of Protection is intended as shown in Table 5.1. For example, for essentially unmodified HEV waters, the management intent is to maintain natural values/condition, and Water Quality Objectives are set accordingly to maintain this natural state. The management goal for waterways which are Slightly Disturbed (SD) is to maintain or improve the health of the water and possibly restore it to High Ecological Value. Moderately Disturbed (MD) systems meet the Water Quality

Objectives and some best practice future development may be approved for these waterways. Highly disturbed (HD) waterways are those with a management goal that aims to improve the water quality over time towards the Water Quality Objectives which can take 20 years or more to achieve.

It is necessary to identify the Level of Protection for waters within management units as part of the development of a WQIP and this depends on knowledge of the condition (relative to natural) of the water in the plan area and stakeholder views on waterway management. Stakeholder input into the categorisation process is part of the required consultation process. Mapping of Environmental Values for each basin can be viewed in the basin profiles (Chapter 6). In using these maps the following points should be noted. All reaches in the Wet Tropics have been identified as having values for aquatic ecosystems and for Cultural and Spiritual values (RAPA, letter to Terrain NRM Inc, August 2012). These values are therefore not mapped, as they are considered present in every catchment. Some basins have two maps, to indicate the differing values in the developed and undeveloped sections of individual reaches. If an EV is indicated as present in a sub-catchment, it means it is present somewhere in that sub-catchment but not necessarily in all of the area.

Some updates have been made to the HEV mapping, which contains both HEVm (HEV maintain) and HEVa (HEV achieve) areas. The main differences from the original dataset are in the coastal waters region where everything outside the GBRMPA plume line is now HEVm. Coastal areas inside the plume pick up a HEVa designation if they are areas such as green zones or fish habitat areas.

The outcomes of these processes undertaken up to 2012 are supplemented by further freshwater condition assessments undertaken by Godfrey and Pearson (2012) and Kroon et al. (2014), and the spatial prioritisation process described in Section 5.2. The levels of disturbance to catchment waterways were assessed by CSIRO (Kroon et al., 2014) and ACTFR (Godfrey and Pearson, 2012) represented by the presence or absence of riparian vegetation. A water quality indicator score was determined along reaches of streams that combined land use and vegetation. The assumption used to justify these two surrogates is that land use in the broadest sense is the main determinant of water quality in streams; and that the riparian zone has a major influence on how land and water interact.

Environmental values and levels of aquatic ecosystem protection were established for all Wet Tropics surface and groundwaters through community consultation (Terrain NRM, 2012; scheduled November 2014). The environmental values, associated aquatic ecosystems level of protection mapping and water type delineation are published at the Department of Environment and Heritage Protection website http://www.ehp.qld.gov.au/water/policy.

A critical knowledge gap is setting freshwater and coastal ecosystem targets that factors in the asset and functional values of these systems, or reducing or halting the threats on the freshwater values. These values and threats are further described in Section 5.2. An example of this gap is correlating the removal of a percentage of fish barriers and blockages within a system and how that activity will improve the health of the reef or the catchment. Investment into research that will assist in target setting needs to occur. For this iteration of the WQIP the target in freshwater and coastal ecosystems in the Wet Tropics will be EVs/WQOs which were finalised in November 2014 by the Queensland Government and are available from the EHP website.. Additional targets will be adopted to reflect the goals and objectives of broader GBR-wide strategies such as the Reef Plan and Reef 2050 Long Term Sustainability Plan (see Section 5.3).

5.2 Defining high value waterways and threats

The spatial prioritisation method used for freshwater ecosystems merges the two spheres of condition and function of the catchments. The foundation of the framework is that the first priority should be to invest in waterways of high value or with multiple values that are subjected to single or multiple threats, and that provide values to marine ecosystem function. Identification of priorities requires identifying values and threats associated with freshwater ecosystem health, and values and threats associated with coastal and marine ecosystem health.

The methodology is based on a Value/Threat/Response framework using the best available spatial and temporal data. Data used in the analysis has been incorporated into a catalogue with key sources of information being Resource Condition Assessments from Kroon et al. (2014) and Godfrey and Pearson (2012); Coastal Ecosystems “Blue Map Eco-calculator” from GBRMPA (GBRMPA, 2013) and the System Repair Spatial Planning Framework from FNQROC (Sydes, in prep). Figure 5.1 conceptualises the landscape zones that Blue Map Eco-calculator and the System Repair Spatial Planning Framework represent.

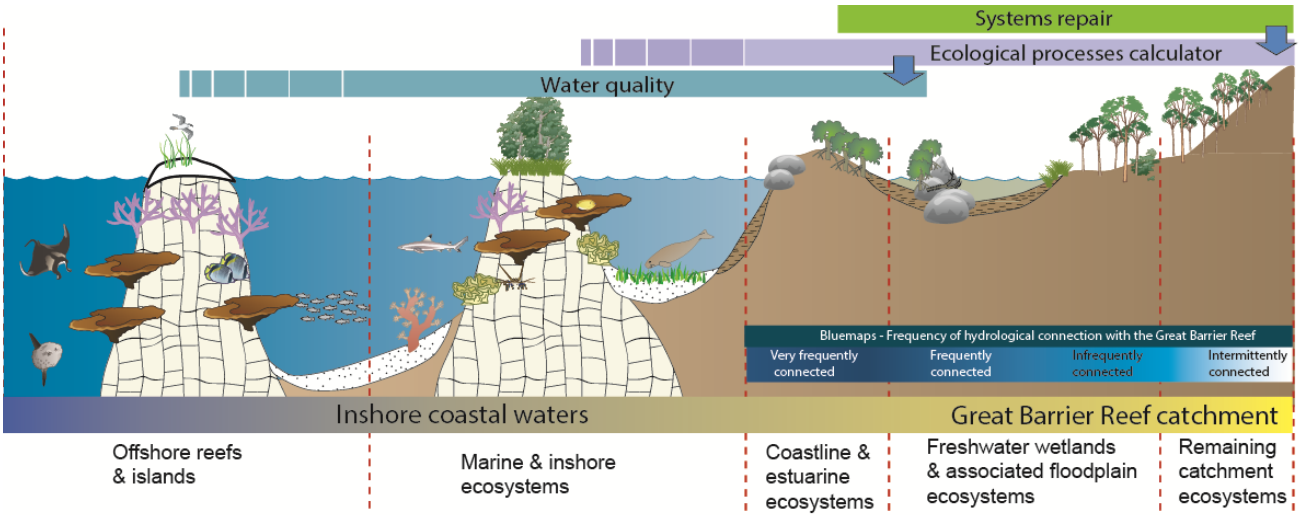


Figure 5.1. Conceptual diagram showing the landscape zones incorporated in the GBRMPA Blue Map Eco-calculator and the System Repair Spatial Planning Framework.

5.2.1 System connectivity and ecological function

The suite of coastal ecosystem tools (basin assessments, blue maps and ecological calculator) developed by GBRMPA have been used to provide a better understanding of the ecological functions provided by natural and modified coastal ecosystems in the Region (GBRMPA, 2013). These tools combine information about how natural coastal ecosystems function/ed in comparison to how they are functioning now based on current land use. Each of the natural and modified coastal ecosystems was scored through expert input for its ability to perform a range of biological, biogeochemical and physical processes. This information highlights ecological function including recharge/discharge processes; ability to trap fine and coarse sediment and nutrients; regulation of carbon; decomposition; flow regulation; and pathway for migratory fish in the Region. GBRMPA Blue maps are combined into this assessment to highlight the hydrological connections between the coastal ecosystems and the GBR. Hydrological connectivity is classified in four classes Table 5.2 from 'Very Frequent Connection' to 'Infrequently Connected'. Using the combined information the Region can be mapped /scored according to the ecological function provided by current natural and modified coastal ecosystems guiding and prioritising where actions for maintaining, restoring and managing ecological function should be undertaken. Figure 5.3 illustrates the level of hydrological connectivity across the Wet Tropics region.

Table 5.2. Level of hydrological connectivity between catchment waterways and the Great Barrier Reef. Source: GBRMPA, 2013.

Simplified Catchment Component Categories	Frequency of Hydrological Connection	Definition
Coastline and Estuarine Systems	Very frequently connected	Direct connections with the GBR occur on a diurnal basis
Freshwater wetlands and adjacent Floodplain Ecosystems	Frequently connected	Direct connections with the GBR occur on at least a monthly basis
	Intermittently connected	Direct connections with the GBR occur for extended periods during seasonal, tidal and flood events
Remaining Catchment	Infrequently connected	Direct connections with the GBR occur through groundwater and overland flows during rain events

The Basin Profiles in Chapter 6 present the ratings for each frequency of connection and provide the areas of key land uses required to be targeted for improving functionality. An example of the Johnstone Basin is provided in Table 5.3.

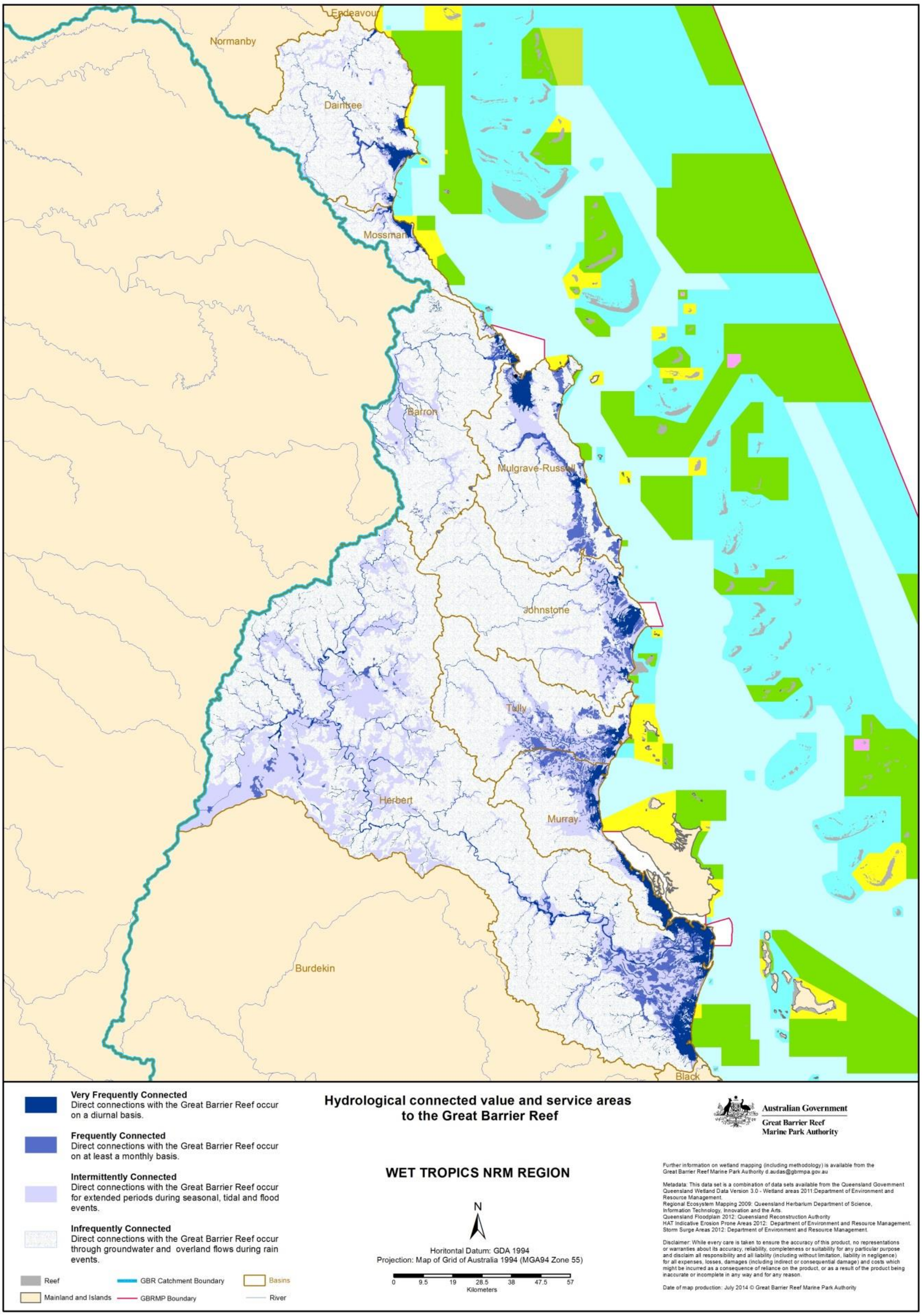


Figure 5.2. Spatial representation of “Blue Maps” outcomes. Source: Map supplied by D. Audas, GBRMPA.

Table 5.3. Targets improving functionality within Hydrological Connection Zones in the Johnstone Basin.

Frequency of Hydrological Connection	Target
Very frequent connection	Maintain and protect current level of processes
Frequently connected	Target dryland production (789ha); intensive uses (145ha); grazing (917ha); irrigated bananas (41ha); ponded pastures (18ha)
Intermittently connected	Target intensive uses (3,094ha); dryland production (15,654ha); dryland sugar (8,394ha); irrigated bananas (4,480ha); grazing (31,206ha)
Infrequently connected	Target intensive uses (2,254ha); dryland sugar (18,464ha); irrigated bananas (2,946ha); grazing (4,133ha)

With the process being spatially explicit, the design of the System Repair Spatial Planning Framework described below allows for incorporation of the GBRMPA Blue Map assessment and allows for freshwater values and threats to be integrated with the functional values of coastal ecosystems.

5.2.2 Wet Tropics System Repair Spatial Planning Framework

The framework has been constructed to inform at two levels. At a regional level, where the aggregate *Values, Threats* and the *Management Response* across the Wet Tropics are considered, and at the catchment level (represented in the Basin Summaries) where impacts on one or more threats are interrogated in further detail and summarised within the Basin unit. Figure 5.2 provides a schematic view of the System Repair Spatial Planning Framework illustrating that the landscapes included in the assessment extend from the coastline and estuarine ecosystems, freshwater wetlands and associated floodplain ecosystems and include the remaining catchment ecosystems.

Data and information utilised in the framework are from both qualitative and quantitative sources. Where data was not available, attributes were populated or calibrated by expert knowledge in a series of workshops (where appropriate).

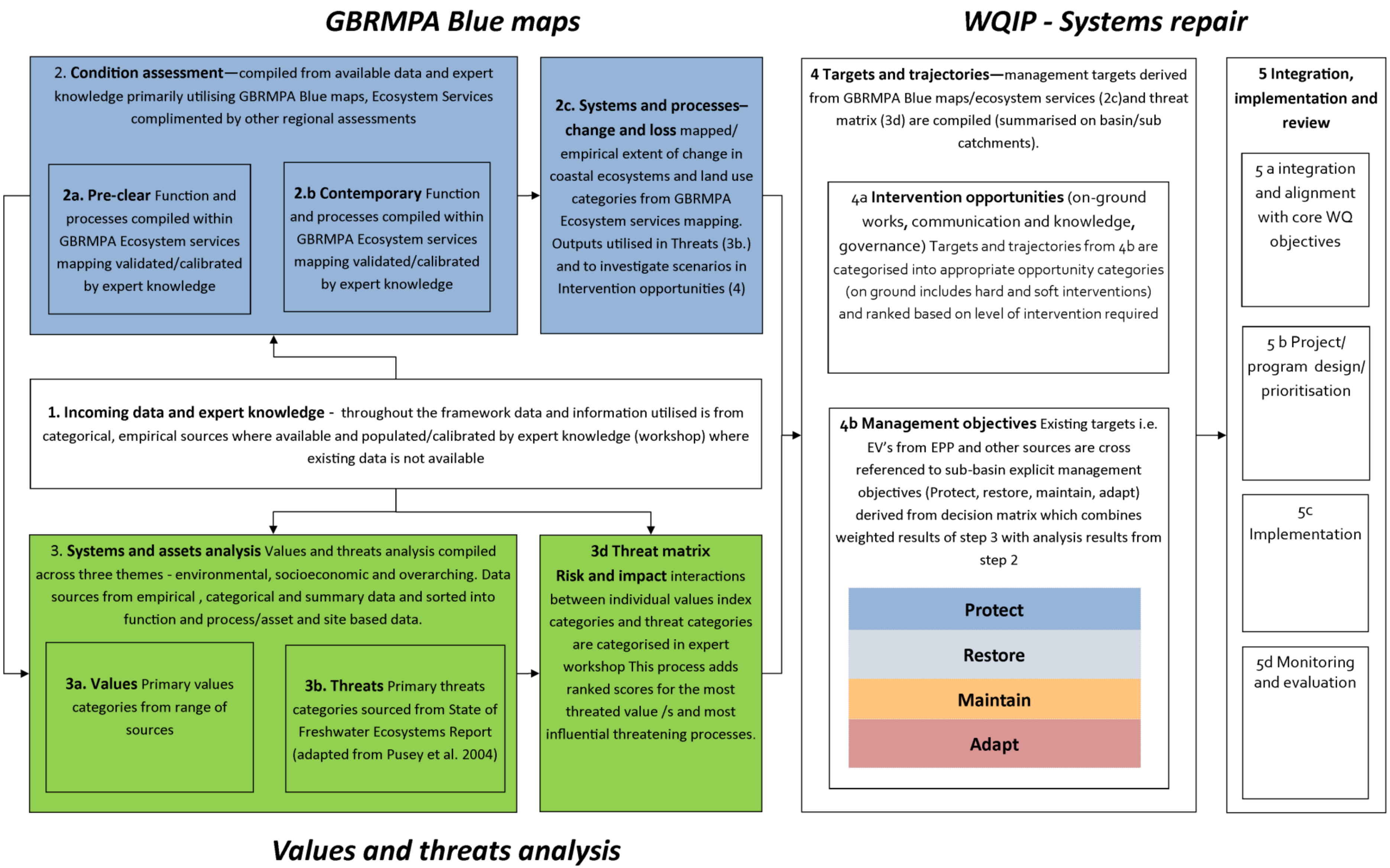


Figure 5.3. Illustration of the System Repair Spatial Planning Framework components.

Systems and Assets Analysis

The framework classifies Values and Threats into two themes **– environmental functions and assets** (as detailed below) and **Socio economic functions and assets**. In this framework, assets are characteristics or attributes of environmental and socio economic systems, and function is the role or the processes that are critical in catchment dynamics.

Following the compilation of available data it was determined the socio economic theme contained too many data gaps and inconsistencies to be deployed with any confidence at a region wide scale. The data is included in the packaged spatial data from the analysis as raw attributes which may assist and guide conversation in planning at a basin or local scale. This is a significant information and knowledge gap which requires future investigation. Future iterations of the spatial planning framework could readily accept improved socio economic data as it becomes available.

Values

Ecological values can be defined as 'the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity' (Bennett et al., 2002). Ecological values include aquatic and riparian biota, waterway habitats and geomorphology, physical and biological river processes, and the influence that one section of the catchment drainage system may have in sustaining other sections in the catchment such as estuaries, floodplains, wetlands and coastal waters (Dunn, 2000). The attributes or characteristics of ecological values that have been incorporated into the prioritisation framework (where validated data was available) are described below and illustrated in Figure 5.4.

Values - Function

1) Recharge discharge processes
   Overland water: Detains water; Flood mitigation; Regulates overland flows; Connects ecosystems
   Groundwater/evapotranspiration: Regulates water flow - groundwater/ evapotranspiration.
2) Sediment capture and release
3) Nutrient - cycling and release, N, P, C & Si
4) Supporting ecological processes
5) Connectivity

Values - Asset

6) Endemism or uniqueness
7) Naturalness (intactness)
8) Protected areas
9) Diversity or richness
10) Irreplaceability, representativeness

Spatial analysis of Values

Figure 5.4 separates each value spatially and conceptualises its integration into a regional waterway aggregate value of each sub-catchment within a basin as shown in Figure 5.5. The level of an aggregate value has been classified into four categories, High; Moderate; Low and; Minor. Attention in the map's interpretation is required as within each sub-catchment there is likely to be a variation of the four categories that can provide guidance for prioritising the threats on the higher values. Further, consideration ***must*** be given to the socio economic values that impact on community perceptions and willingness to undertake system repair works.

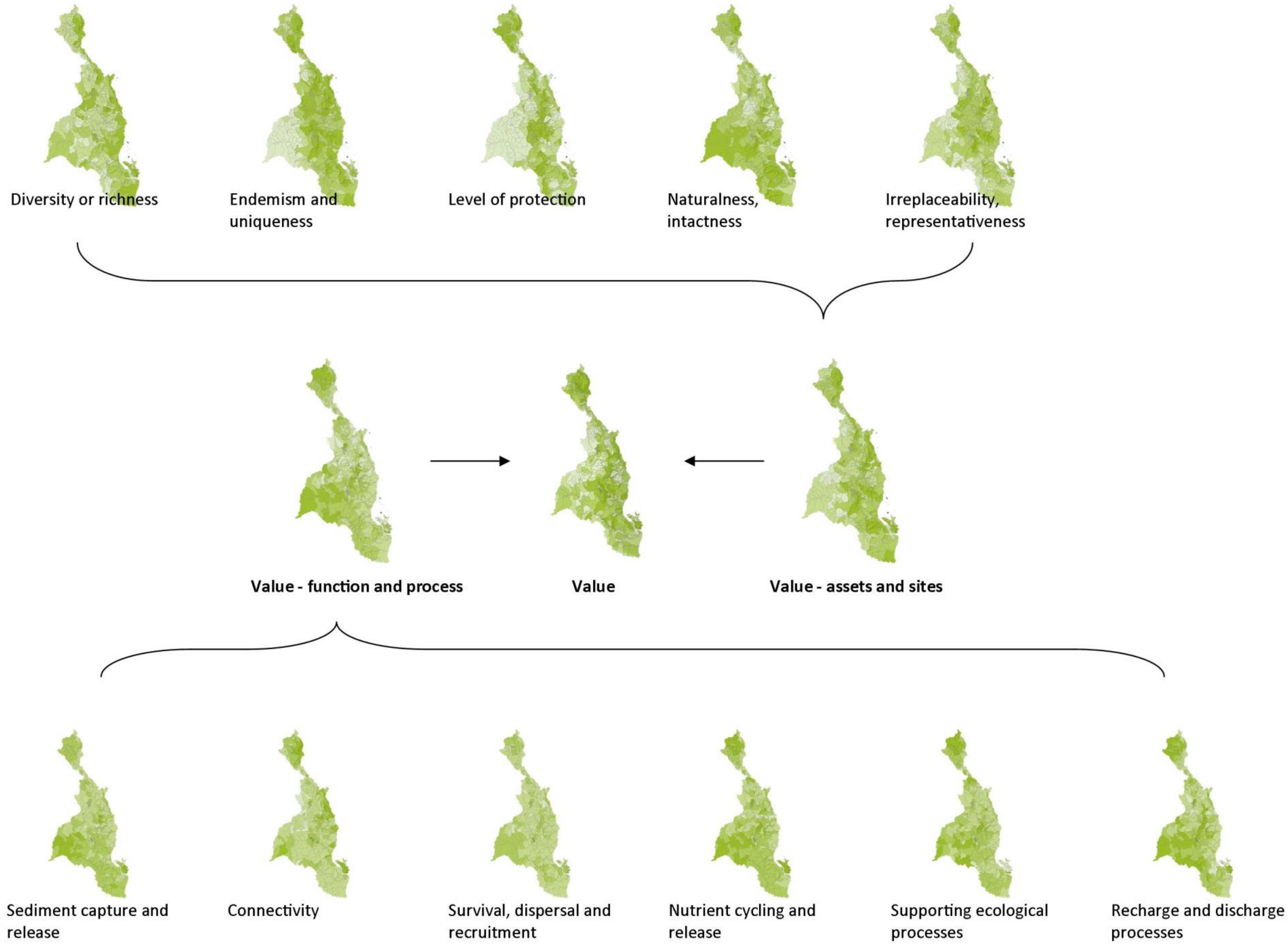


Figure 5.4. Products and outputs of systems repair spatial analysis framework. Freshwater ecosystems values sub-catchment data synthesis.

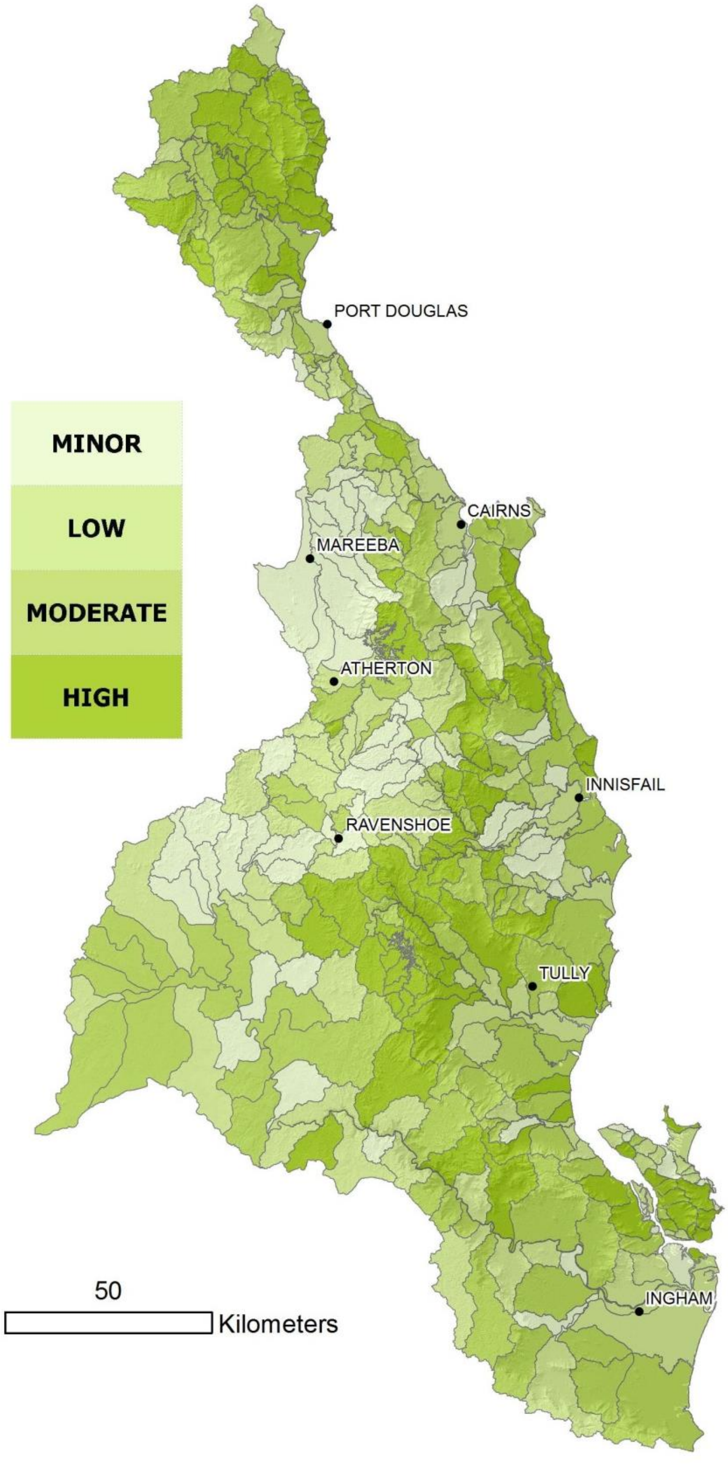


Figure 5.5. Cumulative Values distribution and level rating in the Wet Tropics.

Threats

A number of threatening processes are identified in this report and whichutilisesthe Pusey and Arthington (2003) study. Six of the seven threatening processes to freshwater fishes in North-Eastern Australia identified by Pusey and Arthington (2003) have been modified to encompass threats to freshwater ecosystems for this framework. As with values, threats have been classified into function and assets and most of those described below have been incorporated into the prioritisation framework. The remaining threats can be incorporated as new knowledge becomes available.

Threats – Function

Threats included in the framework:

1) Altered hydrology (included in framework)

Overland water on floodplains and riparian areas provides the attributes of; detaining water, flood mitigation, regulation of overland flows and ecosystem connections. A level of regulating water flow with surface/ groundwater interactions also occurs. A series of specific threats associated with altered hydrology place pressure on the Value attributes including; reduced river discharge, changed seasonality of discharge, increase in peak discharge as a result of land development and hard surfaces, and permanent inundation of ephemeral habitats. The responses of the system include; loss of flow specialist species with dominance of homogenized flow habitats, loss of nursery grounds for floodplain breeding species, and altered residency times for nutrients.

2) Loss of longitudinal and lateral connectivity

Longitudinal connectivity

The viability of populations of many species of fully aquatic organisms depends on their ability to move freely through the stream network. Aquatic fauna are an important component of the biota of tropical and subtropical streams because of their direct influence on ecosystem level processes such as; primary production, organic matter processing, sedimentation and the composition of benthic algal and invertebrate communities (Pringle, 1996).

Lateral connectivity

The lateral expansion of floodplain habitats during flooding creates important spawning, nursery and foraging areas for many fish species and a variety of other vertebrates. Flow regulation by dams, often compounded by other structural modifications such as channelisation and levee banks, normally results in reduced connectivity and altered successional trajectories in floodplain rivers (Ward and Stanford, 1995).

3) Fish Barriers

Modification and alienation of significant aquatic habitat areas, including the construction of barriers to fish passage, can have a significant impact on native fish assemblages. Barriers affect migration of fish and invertebrate species. If adults are prevented from moving past a barrier, spawning migrations may be affected, whilst migration to nursery habitats may be affected if juveniles cannot move past a barrier. As a result, the capacity of habitats beyond the barrier to act as spawning or nursery areas may be reduced, with potential effects on population genetics and dynamics, including stock size (Lawson et al., 2010). It is recognised that the Queensland Government now requires adequate fish passage at new barriers to movement under Waterway Barrier Works provisions under the *Fisheries Act 1994*. Construction or raising of a waterway is classified as operational works under the *Sustainable Planning Act 2009* and requires a development approval.

Barriers to the movement of fish and other animals results in isolation of sub-populations, and consequently, reduced gene flow among these sub-populations within a waterway. Lawson et al., (2010) identify dams, roads, railway, weirs, cane rail and culverts as the key barriers, with roads and cane rail providing the most number of barriers. Many of these structures in the Wet Tropics are existing barriers constructed prior to the commencement of waterway barrier works requirements (noted above) were introduced. The legislation is not retrospective, therefore there is no legal requirement to provide or improve fish passage at such barriers. Table 5.4 highlights the number of fish barriers determined by a study undertaken by CSIRO (Lawson et al., 2010). The large number of potential artificial, physical barriers identified in the desktop analysis were prioritised for management, applying a ranking based on the value of habitat upstream of individual barriers.

Table 5.4. Total number of high, medium and low priority artificial, physical barriers in each of the Wet Tropics basins, and in the Wet Tropics region as a whole. Source: Lawson et al. (2010).

Basin	High	Medium	Low
Daintree	32	123	222
Mossman	19	51	163
Barron	2	181	654
Mulgrave-Russell	17	224	835
Johnstone	10	298	761
Tully	6	227	501
Murray	3	105	201
Herbert	10	256	601
Total	**99**	**1,465**	**3,938**

4) Loss of, and changes in, habitat
In the past, woody debris has been removed from waterways to control flooding, improve navigation, and facilitate easier fishing and swimming. This work has been done with little regard for the importance of the debris as habitat or food in the system. Stream channels have also been modified by dredging and the removal of sand and rock bars.

The interconnection between riparian zones and freshwater ecosystems, including in the Wet Tropics NRM region is acknowledged (Arthington et al., 2010). Riparian zones are the interface between terrestrial and aquatic systems where biological, physical and chemical interactions occur. As such, they are critical components of aquatic ecosystems and influence a variety of ecological patterns and processes in most streams and rivers. Key ecological patterns include enhancement of bank stability (Prosser et al., 2001), the provision of coarse woody material as habitat and substrate for aquatic flora and fauna (Crook and Robertson, 1999), mediation of changes in channel morphology and habitat diversity and refuge from disturbance at a variety of scales (Seddell et al., 1990). Key ecological processes influenced by riparian zones include thermal buffering (Lynch et al., 1984), shading and in-stream primary production (Bunn et al. 1999), as well as nutrient interception, storage and release (Osborne and Kovacic, 1993).

5) Weeds and pests
The key threat of aquatic weeds is the impediment of aquatic connectivity and during periods of minimal flow the blockage will contribute to low dissolved oxygen within the water profile. Aquatic weeds in the Wet Tropics include alligator weed, water hyacinth, hymenachne, glush weed and salvinia. Local Governments have mapped key weeds in Local Area Pest Management Plans and these have been utilised in this framework. With minimal resources for weed management some of the named weeds may or may not be in a Council's priority list.

<u>Threats not included in the framework due to limited data availability at this time:</u>

6) Acid Sulfate Soils
Inappropriate disturbance of acid sulfate soils (ASS) in the Wet Tropics poses a threat to GBR water quality, marine ecosystems, tourism, fishing, soil health and wetland biodiversity. Expansion of sugar cane onto the coastal wetlands and swamps, particularly in the 1970s to 1980s led to drainage and disturbance of acid sulfate soils. Since the 1990s urban development and port expansion have also significantly encroached low-lying coastal areas involving acid sulfate soils. ASS leads to raised acidity levels, lower Dissolved Oxygen, increased algal blooms and as a consequence reduced biodiversity and aquatic fauna movement in the waterways. Table 5.5 shows the areas of level of disturbance of ASS within the Wet Tropics region.

Table 5.5. Area and level of disturbance of acid sulfate soils within the Wet Tropics region. Source: McClurg et al. (2009).

WQIP Area	Area of acid sulphate soils				Existing acid sulphate soil disturbance
	High Probability (ha)	Low Probability (ha)	Total area (ha)	%	
Douglas	10 041	2 526	12 567	8.1	Low
Barron-Trinity Inlet	13 641	0	13 641	8.8	High
Russell-Mulgrave	12 589	4 920	17 509	11.3	High
Johnstone	18 863	5 792	24 655	15.9	High
Tully	41 624	6 687	48 311	31.2	Medium/High
Herbert	32 854	5 162	38 016	24.6	High
Total	129 612	25 087	154 699	100	

Indicative shallow occurrences only

7) Low Dissolved Oxygen

Hypoxia is the major water quality concern in many Wet Tropics' wetlands. Much hypoxia is due to (i) input of organic material from agricultural activity particularly sugarcane fields, which promotes bacterial growth and respiration and depletion of dissolved oxygen, and (ii) nocturnal respiration by excessive growth of invasive weeds, no doubt promoted by nutrient run-off (Pearson *et al.* 2003). These processes were very evident on the Herbert floodplain (Pearson et al., 2003), but not so in the Tully-Murray potentially because of better dilution from greater overland / floodplain events (Pearson *et al.* 2013).

8) Pesticides and Nutrients

Toxic chemical pollution may occur through the application of herbicides and pesticides in agriculture or from urban sources. These chemicals may find their way into local waterways, where they can accumulate in the sediment and eventually enter the food chain. Heavy metal contamination may also occur through the application of trace elements and fertilisers to agriculture land, as well as from mining activities, industrial and urban sources (Kroon et al., 2013).

During the dry season seepage of chemicals via the groundwater into the waterways can increase the concentration of pollutants due to low flow. This accumulation in concentration, especially pesticides, before the commencement of the wet season can have a serious impact to the aquatic biota.

9) Loss in Riparian Connectivity

As illustrated in Figure 5.6, the benefits of riparian vegetation to normal ecosystem function include: habitat and habitat corridors for terrestrial animals and plants; habitat for semi-aquatic animals; shade; filtration mechanisms; vital organic inputs; bank stability; in-stream habitat via roots and snags; basking sites for reptiles; and breeding and roosting sites for many partly aquatic species, ranging from insects to birds. Major breaks in riparian connectivity condition are potentially not suitable for migratory fish species or habitat for sedentary aquatic species.

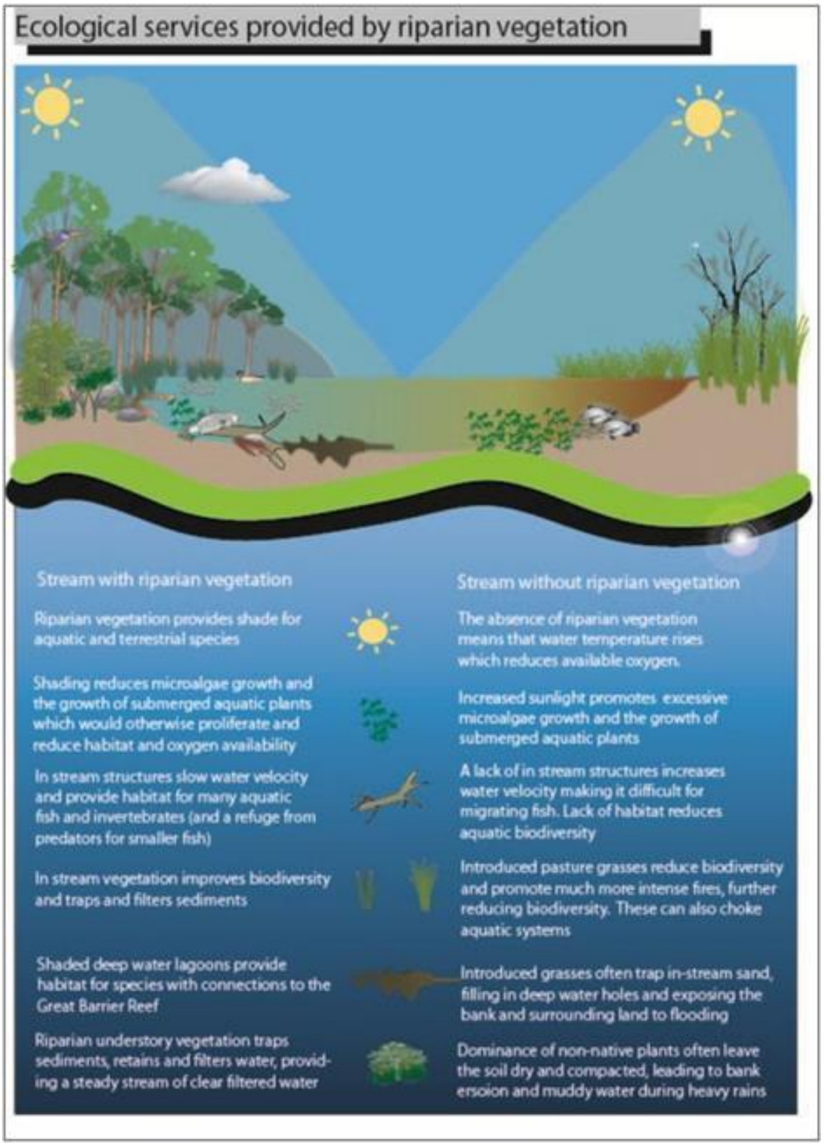


Figure 5.6. Various services provided by riparian vegetation. Source: Supplied by GBRMPA.

With the development of agriculture and urban areas significant lengths and widths of riparian vegetation have been disturbed by clearing, drainage reconfiguration, grazing pressures and weed infestation. Two recent Reports (Godfrey and Pearson 2012, and Kroon et al., 2014) provide extensive assessment of loss of riparian connectivity which is used as one criterion in resource condition assessment. These losses are highlighted in the Basin Profiles, provided as a separate report.

10) Lateral Disconnection
Levelling and drainage to create land for agriculture have resulted in the loss of many wetlands. These agricultural areas are often low in agricultural productivity and experience regular and extensive flooding. This low productivity results in poor or negative economic returns for the farmer. Acid sulphate leachate is an issue in some of these areas. Issues such as agriculture encroachment that can include bund walls and subsequent infestation by Pond Apple (Weed of National Significance) have also contributed to some loss of function.

11) Extreme weather events including climate change
Projections of extreme weather events are expected to affect freshwater ecosystems in the Wet Tropics region as follows (from Kroon et al., 2012):

- Changes in global temperature are reflected in equivalent changes in water temperatures of streams, lakes, wetlands, etc.

- An increase in air temperature will result in increased water temperature, longer stratification periods in reservoirs and lakes, as well as advances in spring events and delays in autumn events.
- Intensification of coastal winds mainly due to higher cyclonic activity will increase shore erosion, alter mixing patterns, and lead to changed salinity conditions in coastal lakes and estuaries.
- Changes in precipitation and evaporation will result in changes of hydrological cycles, river flow regimes, sediment and nutrient transport, and can promote salinisation.
- Flow regime classes will change due to decrease in precipitation.
- Potential reduction of water availability.
- Sea level rise will result in inundation of coastal freshwater ecosystems, saltwater intrusion in coastal groundwater systems, and upstream movement of the tidal influence.
- Increased CO_2 absorption may result in fresh water becoming more acidic, and in some cases an increase in phytoplankton productivity or a decrease in, for example molluscs, is possible.

With sea level rise, greater pressure is applied to fish habitat areas such as mangrove ecosystems and other coastal habitats resulting in a regression of area in existing coastal ecosystems. The cost to fisheries and loss of habitat due to reduced area of mangrove and other coastal ecosystems has not been calculated in the Wet Tropics. Furthermore, low lying coastal areas under production for sugar cane or other commodities has not yet been determined for potential regeneration sites to offset the loss of mangrove extent to improve ecosystem services.

Spatial analysis of Threats

Figure 5.7 separates each threat spatially and conceptualises its integration into a Regional waterway aggregate threat of each sub-catchment as shown in Figure 5.8. The level of an aggregate threat has been classified into four categories, High; Moderate; Low and; Minor. Attention in the map’s interpretation is required as within each sub-catchment there is likely to be a variation of the four categories that can provide guidance for prioritising the threats on the higher values. Further, consideration ***must*** be given to the socio/economic threats that impact on community perceptions and willingness to undertake system repair works.

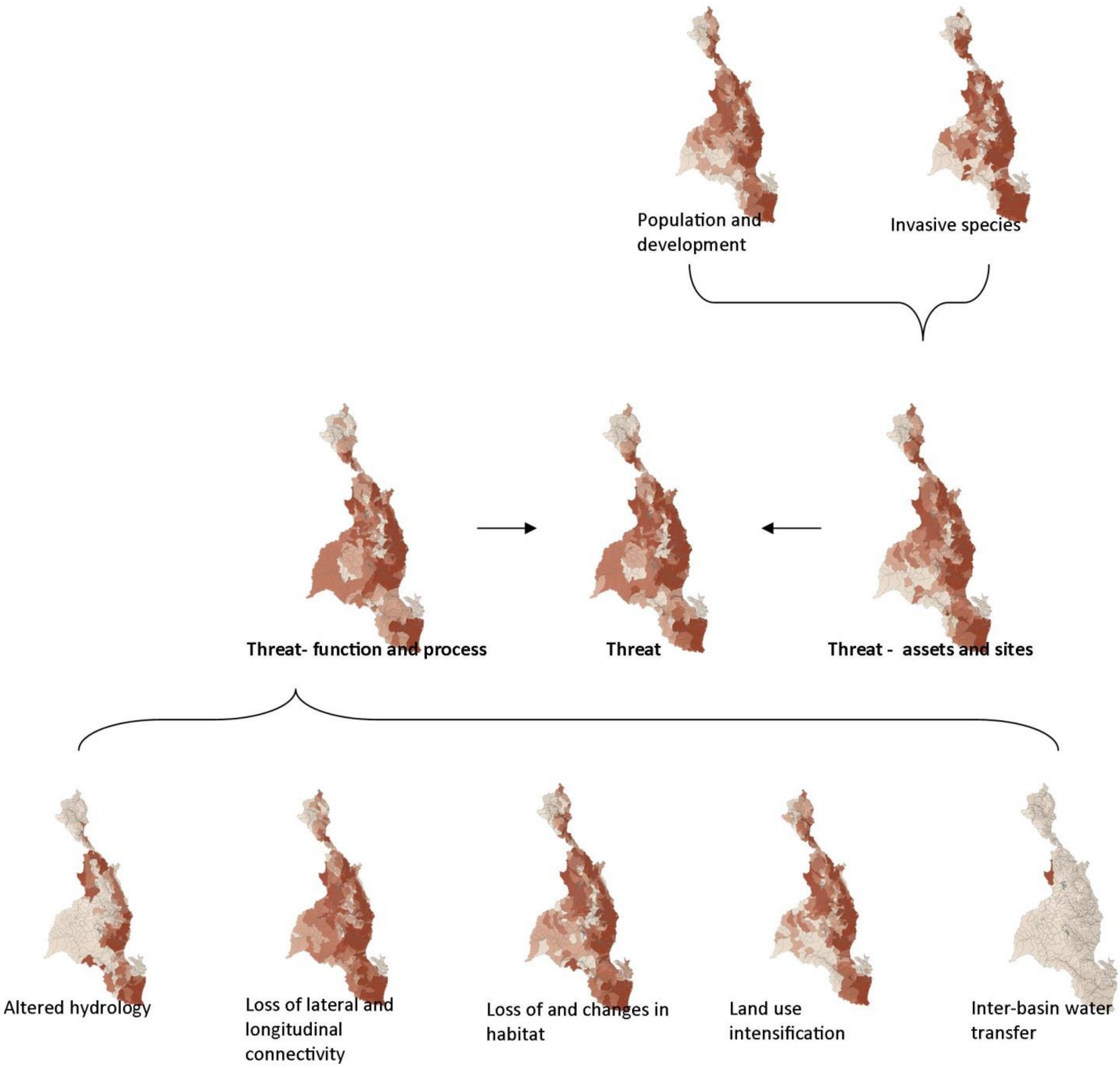


Figure 5.7. Products and outputs of systems repair spatial analysis framework. Freshwater ecosystems threats sub-catchment data synthesis.

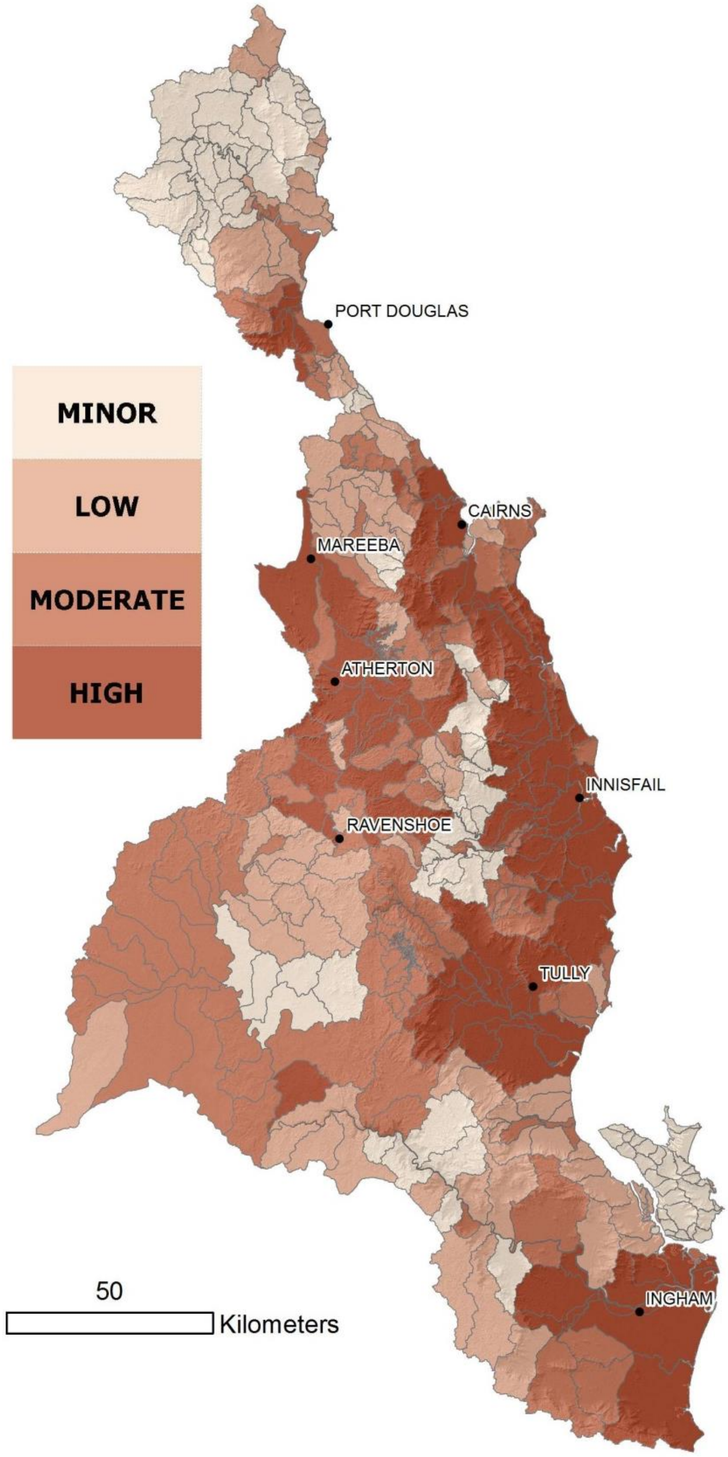


Figure 5.8. Cumulative Threat distribution and level rating in the Wet Tropics.

Threat matrix—Risk and impact

To characterise the relationship and interaction between individual values and threats a matrix was used to map expert knowledge of the relative impact or risk posed by a specific threat to a specific value (Table 5.6). The resulting scores are summarised by both *threat* and *value* to identify key themes and areas of risk per threat or per values category. These factors also provide a relative weighting which can subsequently be applied to describe the sensitivity or importance of each category.

Table 5.6. Environmental Threat Matrix for the Wet Tropics freshwater and coastal ecosystems. Source: Sydes (in prep).

Environmental threat matrix Risk and impact		Function and process values										
		Recharge discharge processes	Sediment capture and release	Nutrient - cycling and release, N, P, C & Si	Survival, dispersal and recruitment	Supporting ecological processes	Connectivity	Endemism or uniqueness	Naturalness, intactness	Protected areas	Diversity or richness	Irreplaceability, representativeness
Function and process threats	Altered hydrology	HIGH	HIGH	HIGH	MODERATE	MODERATE	HIGH	HIGH	HIGH	MODERATE	MODERATE	HIGH
	Loss of longitudinal and lateral connectivity	MODERATE	HIGH	HIGH	MODERATE	HIGH	HIGH	MODERATE	HIGH	MODERATE	MODERATE	HIGH
	Loss of and changes in habitat	MODERATE	HIGH	HIGH	MODERATE	HIGH	HIGH	MODERATE	HIGH	HIGH	HIGH	HIGH
	Decline in water quality and soil chemistry	MINOR	MODERATE	MODERATE	HIGH	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE
	Inter-basin water transfer	HIGH	MODERATE	MODERATE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Site based threats	Impacts of invasive including translocated species	MODERATE	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
	Illicit collection	MINOR	MINOR	MINOR	HIGH	MINOR	MINOR	HIGH	HIGH	MINOR	HIGH	HIGH
	Fish barriers/passage	MINOR	MINOR	LOW	HIGH	MODERATE	HIGH	MODERATE	LOW	LOW	MODERATE	MODERATE
	Population and development	MODERATE	MODERATE	HIGH	MODERATE	MINOR	HIGH	HIGH	HIGH	LOW	MODERATE	MODERATE
Risk assessment	*Weighting by value (1-10)*	*5.0*	*6.7*	*7.1*	*8.8*	*7.5*	*8.3*	*8.3*	*8.8*	*6.7*	*8.3*	*9.2*
	HIGH											
	MODERATE											
	LOW											
	MINOR											

Each category within the matrix is summarised at a sub-catchment scale. The results from the matrix are utilised in two ways:

- The matrix categories in themselves identify the potential impacts/risks between specific or individual threat/value categories (e.g. the impact/risk posed to value *Survival, dispersal and recruitment* by the threat *fish barriers/passage* is high). These relationships can be referenced when decision making or project planning and whilst they are presented as experts assumptions at a bioregion level for this process, they could also be critiqued within a catchment or situation and tuned to better reflect a specific circumstance.
- The potential risk is summarised by category i.e.-*values, endemism or uniqueness* scores a *value weighting* of *8.3.* This score provides a gauge of how vulnerable a specific value is to the range of environmental threats considered in the framework. Within the systems repair spatial planning framework this weighting score is reintegrated into the planning tool to assist identify the value:sensitivity within each sub-catchment planning unit.

Management Objectives

To communicate and categorise appropriate management approaches relative to condition, value and threat within each sub-basin, the four discrete management objectives of Protect, Restore, Maintain and Adapt have been identified. The Management Objectives are aligned with the Management Intent of the categories of Environmental Values as described in the Environmental Planning Policy (Water) (see Table 5.1). Each of these objectives has defined management and ecological targets, together with a required/recommended level and mode of intervention, described in Table 5.7. Table 5.8 identifies the recommended level and mode of intervention for each management category. Note that these recommendations are designed to represent the typical management activities and processes relevant to the objective, and they are not intended to be interpreted as a priority in isolation. It is also important to recognise that the Management Objectives have been applied at a sub catchment scale, but it is likely that smaller areas within a sub catchment display different characteristics.

Assigning Management Objectives

The spatial framework presents an aggregation of values and threats at the scale of sub-catchment planning units (n=586) and subsequently allocates each unit one of four Management Objectives based on their interaction or relationship. The identification and subsequent classification of values, threats and Management Objectives were calculated at a (relative) whole of region scale. Four even breaks were used to define the categories of high, moderate, low or minor (i.e. high = the top 25% of all sub-basin scores, moderate the next 25% etc.). These ratings were then used to define the resultant Management Objective category using a matrix that classifies values and threats (Figure 5.9). In the interests of clarity and to reduce complexity in end-user interpretation, individual (raw) attributes were grouped into thematic relationships to create an unique index score, for example, ‘invasive species’ is the amalgam (unweighted multivariate) of pest fish species diversity and aquatic/waterway specific weed species diversity.

The framework approach presents an objective analysis of the key information available and adopts the principle that the first priority for freshwater and coastal ecosystems should be to invest in waterways of high value or with multiple values that are subjected to single or multiple threats (typically the greatest cost-benefit). A lower priority is to invest in waterways that are subject to the highest pressure (greatest threats or combination of threats) and the least value. A matrix was used to represent these cases to determine the relationships between values, threats and Management Objectives.

The results presented here provide a region-wide overview of the analysis. In implementation of the framework, the interpretation and classification at an individual basin scale will provide more detail on the localised distribution of values and threats. The nature of the spatial analysis underlying the summary outputs presented here can be further interrogated down to individual components or attributes as required.

The spatial framework provides a process for catchment community, NRM bodies, Government agencies and researchers to target investment in both priority sites and key threats for system repair outcomes. For the catchment community, this information should be used in conjunction with existing Catchment Plans and provide a structure for new or revised plans to prioritise activities. Local Government actively participate in NRM particularly the catchment waterway system, undertaking weed control and hard engineering remediation of eroding banks and the installation/replacement of infrastructure such as culverts. The next step is for Terrain NRM to engage these agencies to align this framework to their priority system repair activities, and to influence their allocation for works to reduce impacts and improve catchment health. Alignment with broader initiatives such as the Reef 2050 Long Term Sustainability Plan (LTSP) is also essential, as in Section 5.3, and Table 5.10 specifically.

Table 5.7. Defining Management Objectives and mode of intervention for freshwater and coastal ecosystems.

	Broad Management objective	Description	Management targets	Ecological targets	Assumed condition trajectory/status	DEHP equivalence	DEHP classification
Intact and natural catchments	Protect	Protection of assets, services and processes from current or new threats.	Prevent occurrence of new threats and remove existing threats	Integrity, composition and function of aquatic ecosystems are protected.	Stable Ecological process can continue without adverse impacts from external stressors	High Ecological Value	HEV
	Restore	Early intervention and restoration to repair assets, services and processes to a stable state.	Prevent occurrence of new threats and reverse impacts of existing threats	Integrity , composition and function of aquatic ecosystems are restored to a stable state	Repairable Ecological processes can be reinstated and impacts from external stressors reversed to enable system to return to a stable state	Slightly Disturbed	HEVa*
Disturbed and modified catchments	**Maintain**	Targeted investment to arrest of further deterioration of assets, services and processes.	Minimise occurrence of new threats and reduce impacts of existing threats	Higher value assets and functions of aquatic ecosystems are maintained	Vulnerable Level of disturbance and modification will continue to increase if no intervention is taken. High value assets and functions are able to be maintained with assistance.	Moderately Disturbed	SDa
	Adapt	Adaptation to enable or facilitate essential assets, services and processes or maintain isolated assets	Minimise occurrence of new threats and manage/contain impacts of existing threats	Remaining essential assets and functions for aquatic ecosystems are maintained	Improvable Level of disturbance and modification means many components of the assets and functions are in poor condition and unable to be improved until external stressors are modified	Highly Disturbed	MDa

Table 5.8. Recommended level and mode of intervention by management category for freshwater and coastal ecosystems.

Management Objective	On ground (soft)	On ground (hard)	Knowledge and communication	Governance, policy and legislation
Protect	**Moderate** Early intervention and routine management surveillance for risks from invasive species and BMP maintenance/prevention practices.	**Low** Limited or site specific requirement for hard engineering intervention.	**High** Investigative and applied research of species and systems. Traditional ecological knowledge and cultural understanding. Awareness raising and communication of key values and threats.	**High** Legislative and policy protection supported by appropriate governance and economic processes. Management arrangements which enable appropriate stewardship, partnerships and resources. Incentives and compliance.
Restore	**High** Comprehensive programs to restore condition of vegetation and to remove invasive species.	**Low** Limited or site specific requirement for hard engineering intervention.	**High** Investigative and applied research of species and systems. Traditional ecological knowledge and cultural understanding. Awareness raising and communication of key values and threats.	**High** Legislative and policy protection supported by appropriate governance and economic processes. Management arrangements which enable appropriate stewardship, partnerships and resources. Incentives.
Maintain	**High** Site specific programs to arrest decline in vegetation/water quality and to manage invasive species. Improved land management practices to reduce impacts.	**Moderate** Site specific projects to mitigate impacts on vegetation/water quality/system processes and to manage invasive species. Intervention to maintain functions or processes.	**High** Applied research of species, systems and management practice. Cultural, social and economic knowledge gathering and communication. Prioritisation processes to support decision making.	**Moderate** Regulatory and policy support for implementation of BMP and land stewardship. Incentives and compliance.
Adapt	**Low** Site specific projects to manage key assets or system processes/services. Primary focus on improved land management practices to reduce impacts from external stressors.	**Moderate** Site specific projects to mitigate impacts on vegetation/water quality and to manage invasive species. Intervention to facilitate functions or processes.	**Moderate** Research, communication and knowledge programs to deliver BMP and reduce external stressors on system; or manage key assets and processes.	**Moderate** Regulatory and policy support for implementation of BMP and land stewardship. Incentives and compliance.

On ground (soft)	Weed/pest/invasive species management, revegetation and vegetation manipulation, cultural and practice based works (BMP).
On ground (hard)	Engineering and infrastructure, landscape/hydrological modification, flow management (detention, diversion, absorption), water sensitive design/implementation.
Knowledge and communication	Applied and academic research, community liaison/engagement, knowledge brokering/collation including traditional ecological knowledge, targeted campaigning/awareness raising and education.
Governance, policy and legislation	Protected Areas (and supporting legislation), policy and planning provisions/guidelines, governance and stewardship arrangements/agreements, other legislative protection.

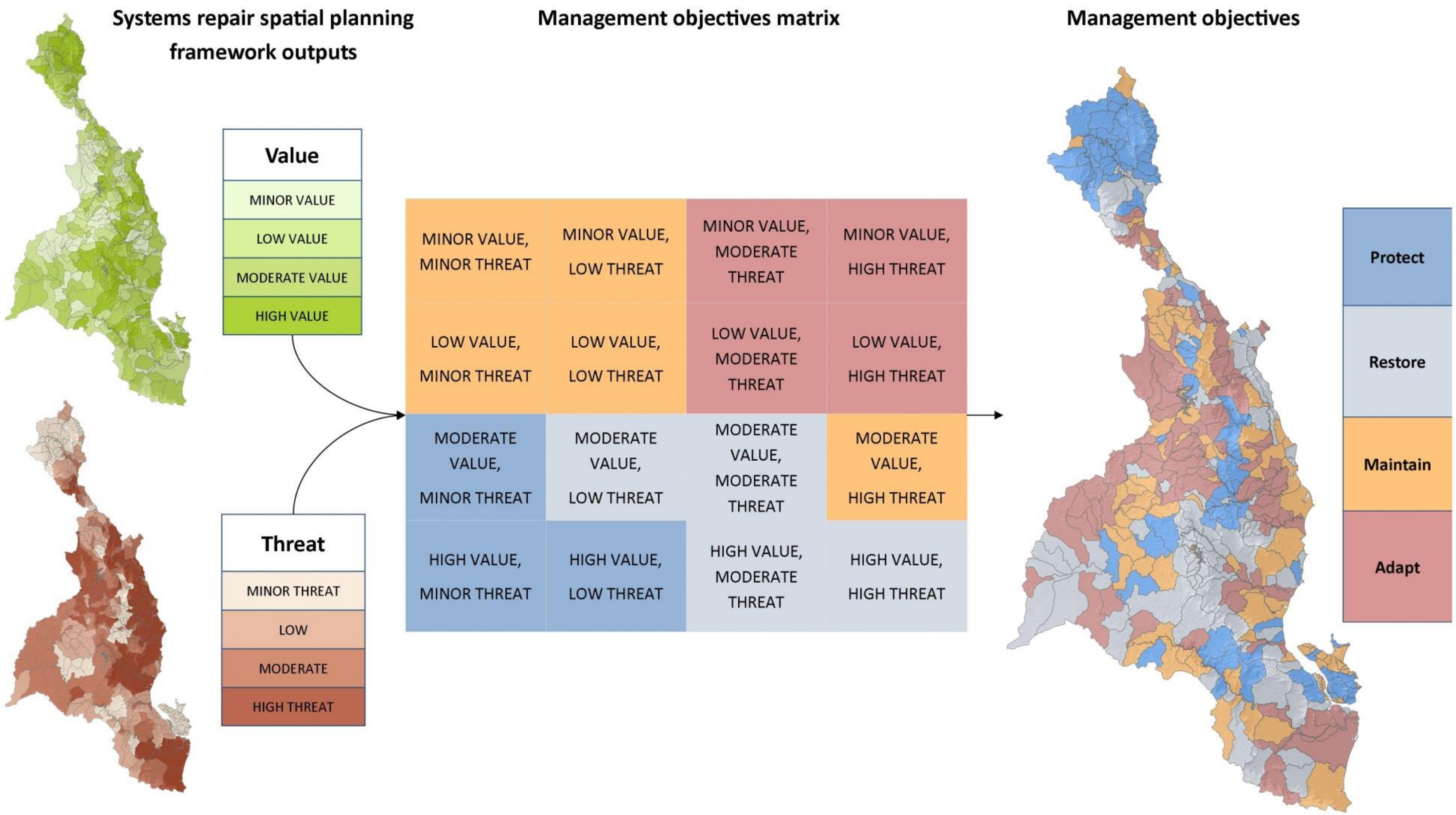


Figure 5.9. Preliminary assignment of Management Objectives for freshwater and coastal ecosystems at a sub-catchment scale, combining the Value and Threat analyses. Note that these outputs require further validation with stakeholders (to be completed 2015).

5.2.3 Limitations

A framework approach is an effective way to deal with the diversity in context and scale of information encountered in analysing freshwater ecosystems. Limitations to the success of any spatial planning process hinge on both data availability and quality and as a general rule the more data available the more reliable will be the results (Macgregor et al., 2011). Data for the framework was sourced from numerous different sources and ranged in context from being freshwater ecosystem specific to more generic spatial data which provides a topographical or land use context. In the process of developing the Systems Repair Spatial Planning Framework a detailed desktop analysis of available spatial data was conducted in order to both filter and organise the information into a data inventory. The results of this desktop analysis and synthesis were then critiqued within several specialist workshops. Data with major omissions in either coverage or uniformity in context/content were removed from final analysis if an appropriate solution (surrogate or reinterpretation) could not be identified. A significant outcome apparent in the data collected was the limited coverage and uniformity of spatially explicit socioeconomic data at a regional scale. **Therefore, socio economic data was excluded in the final analysis. This significant exclusion will require careful consideration of socio economic and cultural values and threats at a basin and local scale**. Other omissions or caveats apply in particular to information on species or community composition where data may be either modelled based on limited distribution information or may vary in comprehensive detail from location to location as an artefact of survey and research focus and efforts.

The nature of the translation of multiple spatial scales required for the synthesis of data into the framework analysed requires a certain degree of simplification of data used. The sub-basin planning unit (n=586) adopted in the framework requires that many quantitative data be interpreted as a mean or a maximum in the spatial query. As a result the detail of locality specific datasets by the generic nature of the analysis will have more resolution in their raw state (e.g. the maximum number of endemic species occurring within all vegetation in planning unit). For more topographic and coverage based queries this is not the case, an accurate summary on a sub-basin scale is achieved (e.g. the total area of Wet Tropics WHA within a planning unit).

It is assumed that many end users of the WQIP will be consumers of spatial data and not generally involved in the manipulation or analysis of spatial data. To cater to this situation, the data inventory with the framework provides the building blocks for further investigation and interrogation and at the same time demonstrates in a transparent way the groupings, classifications and synthesis of complex individual data relationships into a more generic translation. Figure 5.10 shows how the framework could be applied more generically to support decision making for individual assets.

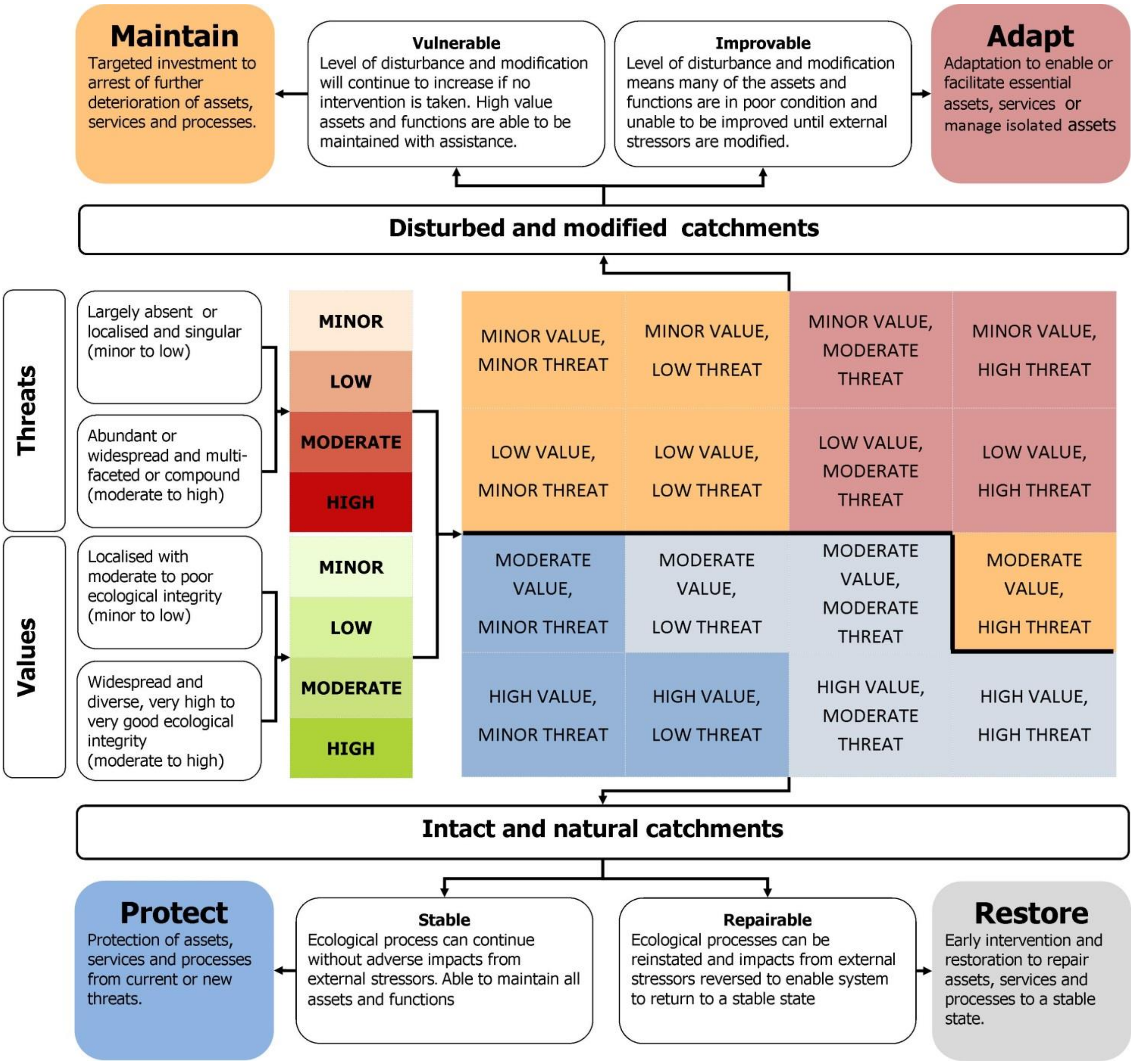


Figure 5.10. Adaption of the decision support approach that could be used outside of the Spatial Planning Framework for decisions around individual assets.

5.3 Implementation of the Wet Tropics Systems Repair Spatial Planning Framework

The Wet Tropics Systems Repair Spatial Planning Framework (herein referred to as the SPSPF) provides a relative overview of threats and values of several well documented assets and ecosystem processes and functions across the Wet Tropics planning area. The framework will be hosted by Terrain NRM in the future and will provide guidance to further development of the WQIP strategies and the Wet Tropics NRM Plan. Implementation will require both detailed consideration and critique at a local scale, and an ability to incorporate new and improved information and knowledge as an integral process of implementation.

Implementation of the SPSPF needs to be bought into the context of a number of other planning processes. The Wet Tropics Regional NRM Plan is currently being updated and reviewed specifically to incorporate activities to mitigate and adapt to a changing climate. Estuaries, coastal floodplain and inshore ecosystems are important from both climate change mitigation and adaptation perspectives and will be prominent in the revision of the regional NRM Plan. From a climate change mitigation perspective, repairing the productivity and functionality of these ecosystems is a priority. Likewise with sea level rise and the likelihood of more extreme events, repairing coastal ecosystems to ensure foreshore buffering and resilience to extreme events is a priority.

At a broader scale, the Great Barrier Reef Marine Park Authority Outlook Report 2014 (GBRMPA, 2014a) clearly identified water quality and loss of estuarine and inshore coastal ecosystems as key threats to the resilience and health of the GBR. This potential outcome is reinforced at regional and local scales in the SPSPF which emphasises that the health of a waterway reach is dependent on good connectivity in aquatic movement, riparian vegetation linkage and lateral transfer of biota, sediment and nutrients. The Outlook Report has placed levels of risk to the GBR ecosystem on several threats included in the SRSPF, and ranked many of them as Very High or High risk (Table 5.9).

Table 5.9. Risks associated with catchment threats on GBR. Source: GBRMPA (2014a).

Threat	Likelihood	Consequence	Risk
Modification of coastal habitats	Almost certain	Major	Very high
Nutrient & Sediment runoff	Almost certain	Major	Very high
Sea level rise	Almost certain	Major	Very high
Barriers to flow	Almost certain	Moderate	High
Pesticide runoff	Almost certain	Moderate	High
Acid sulphate soils	Possible	Moderate	Medium

Following the release of the Outlook Report and the strategic environmental assessment of the GBR WHA and adjacent coastal zone (GBRMPA, 2014b), the UNESCO World Heritage Committee identified that a long-term plan for the Reef was essential to address these threats. In March 2015 the Reef 2050 LTSP[21] was released (see Section 3.3.3). There is also scope to link with specific tasks from the LTSP including development of the regional Reef Recovery Plans.

Many of the targets and actions in the LTSP are strongly aligned with the intent of the SRSPF, particularly with regard to ecosystem health, water quality and community benefits (Table 5.10). The SRSPF is designed to provide guidance for prioritisation at a regional and basin scale. At the site-specific level, further investigations, planning and most importantly, community consultation is required. Catchment communities, including Local Government have implemented remediation activities over many years within the region’s catchment drainage systems. Most of these activities address the threats of altered hydrology, riparian connectivity and aquatic connectivity. Despite this potential, there is still considerable effort required within the Wet Tropics region and across the entire GBR to identify the short, medium and long term strategies required to meet the LTSP targets at a regional and local scales.

It is recommended that implementation of the SPSPF occurs in several, phased steps:

1. Planning and consultation to identify the priority areas for management intervention in the context of the Management Objectives identified in the SRSPF.
2. Implementation of a set of short term (1 to 2 year) ‘no regrets’ system repair projects.
3. Development of a regional system repair strategy to deliver regional outcomes for supporting coastal ecosystem function and landscape connectivity.
4. Implementation of larger scale priority projects across the region.

Table 5.10 outlines the objectives, targets and actions for the Wet Tropics system repair strategy and identifies how they are aligned with regional implementation of the Reef 2050 LTSP.

[21] http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan

Table 5.10 Objectives, targets and actions for the Wet Tropics system repair strategy that are aligned with the Reef 2050 LTSP.

Reef 2050 Long Term Sustainability Plan Targets and Actions	Specific actions of the Wet Tropics WQIP
Objective: **EHO2: The Great Barrier Reef World Heritage Area retains its integrity and system functions by maintaining and restoring the connectivity, resilience and condition of marine and coastal ecosystems.** **Target: EHT3:** **There is no net loss of the extent, and a net improvement in the condition, of natural wetlands and riparian vegetation that contribute to Reef resilience and ecosystem health.**	•
Ecosystem Health	
Protecting and Restoring	
EHA7: Prioritise functional ecosystems critical to Reef health in each region for their protection, restoration and management. EAH10: Improve connectivity and resilience through protection, restoration and management of Reef priority coastal ecosystems including islands through innovative and cost-effective measures.	i. Work in collaboration with GBRMPA to validate and review the outcomes of the existing GBRMPA coastal ecosystem tools including Blue maps and Ecological Calculator assessment for the region to identify priority functional ecosystems in 2015-2016. ii. Integrate the outcomes with the SRSPF to define a set of projects relevant to protecting, restoring and maintaining the values of these priority ecosystems through a series of community and expert workshops (2015-2016).
EHA13: Identify and prioritise key sites of high ecological value and implement recovery programs (Reef Recovery Plans).	iii. Provide the outcomes of the WQIP and the SRSPF to GBRMPA to inform the development of the Reef Recovery Plan for the Wet Tropics region.
EHA14: Implement ecosystem health initiatives through the Reef Trust investment strategy.	iv. Utilise the outcomes of (i) and (ii) to guide the design of projects that are suitable for investment through the Reef Trust investment strategy.
EHA15: Improve mapping, modelling and monitoring of ecosystems important for the protection of the Reef to inform planning, assessment and decision making.	v. Maintain the SRSPF to ensure that the datasets used to assess values and threats to freshwater and coastal ecosystems are up to date, and incorporate new datasets as information becomes available. vi. Collaborate with the Queensland Wetlands Program and GBRMPA to identify key information gaps for mapping, modelling and monitoring of important coastal ecosystems in the region.
Reducing impacts	

Reef 2050 Long Term Sustainability Plan Targets and Actions	Specific actions of the Wet Tropics WQIP
EHA18: Avoid, mitigate or offset impacts on marine and coastal ecosystems to restore Reef resilience and ecosystem health.	vii. Use priorities identified in the WQIP to guide actions on-ground to improve Reef resilience and ecosystem health. viii. Identify gaps in knowledge and understanding and guide investment to fill these gaps.
EHA20: Strengthen the Queensland Government's vegetation management legislation to protect remnant and high value regrowth native vegetation, including in riparian zones.	ix. Ensure that NRM staff are informed regarding current vegetation management legislation, to facilitate protection of riparian areas.
EHA24: Work with local councils to build their capacity to effectively implement coastal planning laws and policies to protect the Reef.	x. Continue to engage in the FNQROC and directly with local councils to communicate the outcomes of the WQIP and facilitate uptake of practices that promote protection of coastal and marine values in coastal planning. xi. Build on existing programs and neetworks i.e Reef Guardian Council Program. xii. Share and exchange information to ensure tools and knowledge is consistent. xiii. Provide support to build expertise and capacity for local councils as required.
Monitoring and Reporting	
EHA31: Communicate the findings of the Great Barrier Reef Coastal Ecosystems Assessment Framework – basin assessments and encourage their use in determining priorities for protecting and restoring coastal ecosystems and in taking actions likely to improve Great Barrier Reef health and resilience.	xiv. Establish and implement a supporting communication plan to share information and knowledge. xv. Exchange data and findings.
Community Benefits: CBT2 Target *Community participation in stewardship actions to improve Reef health and resilience continues to grow.*	i. Engage with existing networks such as the Reef Guardian Programs to capacity build community and engage stakeholders.

Chapter 5: Adopting a holistic approach to water quality improvement in the Wet Tropics

6. Delivery Mechanisms

Implementation of the WQIP will require actions across a range of land uses including agricultural and urban areas, and areas where ecological functions such as water retention, sediment trapping and hydrological connectivity have been modified. However, it is clear that changes to management of agricultural land to improve water quality runoff and actions that restore coastal ecological function will be required across all basins.

The delivery mechanisms described in Section 4.2 are relevant to both Strategies of the WQIP and involve a combination of:

- Regulation and policy to achieve minimum standards;
- Financial incentives to encourage change;
- Extension to facilitate technology transfer, education, communication, demonstrations and to provide support for community networks; and
- Technology change including of improved land management options, such as through strategic research and design (R&D), participatory R&D with landholders, and provision of infrastructure to support a new management options.

The implementation of this WQIP will require BMP programs at a larger scale than has occurred previously, and with different levels of extension and incentives than current programs. At the outset of the new Implementation Plan, careful consultation and continued partnerships with the relevant industries are needed to help understand the reasoning and logic behind the changes to current approaches.

However, there are a number of factors affecting the choices of delivery mechanisms that are likely to change in the future. These are discussed below in Section 7 and have implications for the longer term implementation strategy for meeting the proposed targets.

7. Wet Tropics in 2050

7.1 A changing landscape

Section 2.3 identified the key threats to the highly valuable ecosystems in the Wet Tropics region. A number of these threats are likely to change over time, which will have implications for the implementation of a long term strategy for water quality improvement in the Wet Tropics region. The key influences are summarised below.

Population projections

Population in the region is expected to grow over the next 20 years by an average of 1.5% per year (DAFF, 2014). The increase is largely due to net migration, including people recently retired or seeking a lifestyle change, with natural increases remaining relatively steady. In comparison, Queensland is expected to have an average annual growth rate of 1.8 per cent over the same period. The *Far North Queensland regional plan 2009–2031* has identified that the majority of the region's growth will be accommodated in a corridor south of Cairns including the Mount Peter area. A large scale coastal development north of Cairns (AQUIS) is also likely to increase population numbers in the urban areas north of Cairns.

Agricultural expansion

A number of opportunities have been identified for agricultural industries in the region in the Queensland Agricultural Land Audit (2014) which may affect the scope of agricultural land use in the Wet Tropics in the future. Of greatest significance, there is the biophysical potential to significantly expand sugar cane and other crops in the upper Herbert catchment. Large areas of potential have been identified, including 206,908ha of A class land. Water-storage facilities would need to be constructed for a new irrigation district and other limitations such as those associated with mill capacity and options for expansion would need to be addressed. However, possible sites for dams that would be able to service an irrigation district of this scale have been identified at the confluence of the Herbert River and the Millstream

River. Further detailed soil, surface water and groundwater studies would need to be undertaken before expansion. Some investigations are reported in the North Australia Report 2014[22].

Potential areas for all industries have been identified within the region through the Queensland Agricultural Land Audit (2014). These areas include where the majority of current production occurs as well as where production could potentially occur (based on biophysical parameters such as agricultural land classes 'A' and 'B' slope and temperature) and are not exclusive (the same areas have been assessed for each industry). However, while there is significant potential for expansion when considering the supply side of markets, opportunities will only arise where the region is competitive into key domestic and international markets.

- ***Broadacre cropping:*** ~9 percent of the region has biophysical potential (equates to a further 8.5 percent) mostly in the Mareeba Dimbulah Water Supply Scheme area. Of the land identified as having biophysical potential, 75 percent is currently used for grazing and 14 per cent for sugarcane production.
- ***Sugarcane production:*** ~11 percent of the region has biophysical potential (equates to a further 10 percent). Of land identified as having biophysical potential for sugarcane, a majority is currently used for grazing. These areas are shown in Figure 7.1. The Mareeba mill is undergoing expansion to process additional sugarcane harvest and also to process syrup into raw sugar. This provides potential for an immediate increase in sugarcane cultivation in the surrounding area. The upper Herbert River area has been identified as having biophysical potential for sugarcane, but poor transport and lack of infrastructure limit this development. Areas that offer the most potential for development of the sugarcane industry are expansions on existing growing areas. These are areas that have established irrigation systems, access to mill processing, sufficient road infrastructure and high solar radiation for optimal biomass production (such as the Mareeba Dimbulah Water Supply Scheme area). However, a relatively high Australian dollar, relatively high establishment and production costs (even when expanding existing schemes), and international market competition are likely to constrain growth opportunities in the short to medium term.
- ***Perennial horticulture production and annual horticulture production:*** ~13 per cent of the region for each industry (equates to a further 12.5 percent). A majority of land identified as having biophysical potential for either perennial or annual horticulture is currently used for grazing. Many areas with biophysical potential for horticultural production within the Mareeba Dimbulah Water Supply Scheme are considered favourable for development. Labour infrastructure, including on-site accommodation and localised support for workers, is well established. Water supplies are reliable and transport infrastructure to the major population centres is largely established, but still requires further improvements. Distance to market and competition from regions closer to domestic markets (e.g. Burdekin) will constrain growth for some products (bananas are probably the exception). However, counter-seasonal and niche market opportunities will provide some opportunities for growth. Export market opportunities will also be constrained by both logistical issues (infrastructure and timing to markets), expansion priorities in potential export markets (i.e. South East Asian countries remaining self sufficient), and changing consumer preferences towards more highly transformed product (where Australia has a significant competitive disadvantage).
- ***Intensive livestock production:*** ~ 15 per cent of the region has biophysical potential. Expansion of feedlot activities in conjunction with the development of broadacre and fodder cropping enterprises would be possible in the upper Herbert River area, provided infrastructure (such as irrigation and water storages) and road transport were further developed. Coastal finishing of cattle from western Queensland provides significant opportunity for feedlot expansion in the region. However, climatic factors (such as high rainfall and its impact on waste and odour management) need to be considered. The commercial opportunities for expansion will be linked to growth in export demand and production in broadacre grazing (see below).
- ***Aquaculture:*** Potential expansion of along the coast of 7453 hectares (0.1 per cent of the region). The soil, slope and access to water make these areas feasible sites. Currently, most products are road freighted for domestic markets, but small amounts are air freighted internationally. Planning considerations may impact the establishment of new aquaculture development areas. In addition, Australian producers tend to be relatively high cost and this will constrain growth. Hwever, as consumers become increasingly aware of product quality issues in aquaculture (e.g. water quality) and are prepared to pay more for safer product, the likelihood of aquaculture expansion will increase.

[22] Recommendations in the North Australia Report 2014. PIVOT NORTH, Inquiry into the Development of Northern Australia: Final Report. Joint Select Committee on Northern Australia, September 2014. http://www.aph.gov.au/~/media/02%20Parliamentary%20Business/24%20Committees/244%20Joint%20Committees/JSCNA/Final%20Report/Final.pdf

- ***Dairy:*** Based on the declining numbers in recent years, the region is not considered a potential growth area for dairy unless an export market for fresh milk supplies can be secured. This would depend on the development of extended shelf-life storage and improved shipping technology.
- ***Grazing:*** ~80 percent of the region has biophysical potential. The biggest restrictions on the western area of grazing are limited water access and grazing circles around watering points. Despite this, export opportunities for northern Australia will expand over the medium to longer term as Australia has a genuine competitive advantage in beef production. As incomes rise in South East Asia and populations become more urbanised, demand for red meat is increasing significantly faster than population growth. In addition, opportunities for major expansion of production in many South East Asian countries is constrained. While the timing of pressure to expand in the Wet Tropics may be uncertain and other areas may expand/intensify sooner (e.g. Burdekin/Fitzroy) due to logistical advantages), risks from the intensification of livestock production are significant.
- ***Forestry:*** There is biophysical potential for increased forestry production in the region from native hardwood, plus from softwood and hardwood plantation resources. However, for plantation forestry, the risk of cyclone damage will need to be carefully considered, given the recent experience with plantations in the region. Increased forestry production would provide further resources for existing timber processing facilities within and near to the region once increased supply comes onstream.
- There is interest in expanding the rice industry in the region. Some crop trials are producing promising results (Beilharz, 2012). However, while rice production may be possible, commercial expansion in such a highly competitive world market is less likely in the short to medium term.
- Potential for introducing chia as a seed crop. It is currently grown in the Ord area and is attracting premium prices. Parts of the Mareeba Dimbulah Water Supply Scheme area have been identified as suitable for chia.

There are also a number of impediments to agricultural expansion in the region at present including road transport costs which are increasing with rising fuel prices and there is no timely, reliable rail alternative for the supply of fresh produce to southern markets, availability of water supply infrastructure, access to service infrastructure such as sugar mills, biosecurity issues and external market forces. Liaison with local technical experts indicates that the socio economic limitations to these potential expansions are likely to outweigh the potential biophysical opportunities, and therefore, this level of expansion or intensification is a relatively low risk to the implementation of the WQIP.

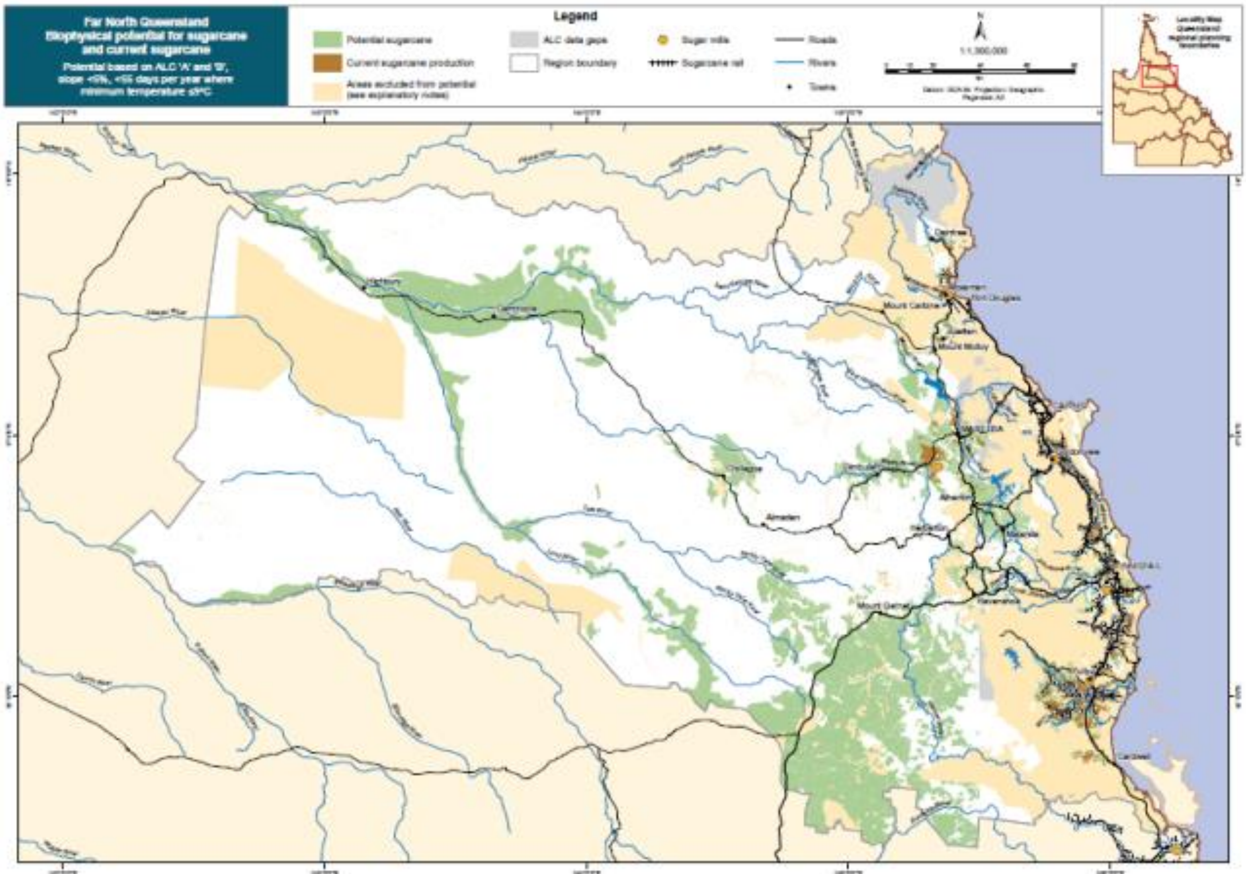


Figure 7.1. Far North Queensland Biophysical potential for sugarcane and current sugarcane. Potential based on Agricultural Land Classes ‘A’ and ‘B’, slope <5%, <55 days per year where temperature is less than or equal to 9C. Source: QDAFF (2014).

Climate change

Periods of higher-than-normal sea surface temperature are stressful to corals and have caused severe and spatially-extensive coral bleaching events in the Great Barrier Reef since the 1980s (Hoegh-Guldberg et al., 2007). The 1998 and 2002 major bleaching events affected reefs throughout the Great Barrier Reef and each event is thought to have caused approximately 5% coral mortality, including in the Wet Tropics region (Berkelmans et al. 2004). Modelling of sea temperatures using the IPCC AR5 Representative Concentration Pathways (RCP) predicts that severe effects will be evident by 2030, with annual bleaching conditions associated with atmospheric CO_2 equivalent concentrations of 510 ppm (under RCP6.0) (van Hooidonk et al. 2013).

The frequency of coral diseases has been linked to stressors such as thermal stress (Selig et al., 2006; Bruno et al., 2007) and elevated nutrients (Bruno et al., 2003, Haapkyla et al., 2011). On GBR inshore reefs the incidence of disease has shown repeated increases following major flood events (Thompson et al., 2011) and has been documented in corals in the Barron, Daintree , Johnstone and Russell-Mulgrave sub-regions of the Wet Tropics, hindering post-cyclone recovery of reefs (Thompson et al., 2013).

Tropical seagrasses require water temperatures of 25 - 35°C and when SST rises to 35 - 40°C, photosynthesis declines due to the breakdown of photosynthetic enzymes (Ralph, 1998) and can result in reduced growth rates (Waycott et al., 2011). Although temperature tolerance varies between species and seasons (Campbell et al., 2006; Perez and Romero, 1992), overall seagrass can only survive temperatures greater than 40°C for short periods, and prolonged exposure leads to the ‘burning’ of leaves or plant mortality (Waycott et al., 2011). In the Wet Tropics, no extreme water temperatures have been recorded within the seagrass canopy over the past few years of monitoring (McKenzie et al. 2014).

Studies on Michaelmas Cay northeast of Cairns have linked poor seabird foraging and breeding success to localised increases in sea surface temperatures and intense ENSO conditions (Smithers et al., 2003; Peck et al., 2004; Devney et al., 2009; Devney et al., 2010). Collectively this evidence has generated sufficient concern regarding the conservation of seabirds under a changing climate to initiate further investigation of available GBR seabird data and monitoring protocols (GBRMPA, 2006).

The changing climate as observed and predicted within the Great Barrier Reef will increase the frequency with which coral reefs, seagrass meadows, and coastal wetlands are being disturbed by extreme events such as floods, tropical cyclones and thermal stress. Response to and recovery after these acute events will be exacerbated by chronic poor water quality, which also influences other drivers of ecosystem condition such as crown-of-thorns starfish outbreaks and disease. The magnitude of impacts and the ability of ecosystems to recover from these events or transition to an alternative state, will depend on: (i) their condition prior to the disturbance, (ii) chronic environmental pressures, such as water quality, and (iii) the return period between events compared with recovery time (Johnson et al., 2013). It is for this reason that addressing chronic stressors caused by human activities, like degraded water quality, are important for maintaining and improving ecosystem condition. Improving water quality can decrease the sensitivity of corals and seagrasses to episodic disturbances when they occur, and improve recovery post-disturbance (e.g. Wiedenmann et al., 2013, Thompson et al., 2013). The events of recent years have shown that disturbances can occur in some areas every year for consecutive years and can even occur during the same year in some areas. As the return period between disturbances decreases, recovery will depend on maintaining ecological resilience and minimising chronic pressures such as poor water quality (Johnson, 2014).

7.2 Future projections

There is the opportunity to project the future trajectory of the Wet Tropics region in 2050. *Note: Much of the following information is relevant across the GBR and was derived from the Burnett Mary WQIP drafted by Natural Decisions.* The concepts outlined below also apply to a range of other highly valued and threatened marine and freshwater assets in other Australian states. There are also opportunities to learn from other parts of the world where progress is being made, albeit not always smoothly (Greenhalgh and Selman, 2012; Roberts and Craig, 2014 amongst many others).

The work underpinning this WQIP, as well as much previous work conducted in Queensland through Reef programs, shows a number of continuing themes, listed below.

- The GBR region is under great and increasing threat. Without even greater action than is occurring now, by 2050, much more of its value will be lost.
- Sediment, nutrients and pesticides from agricultural sources are only one of the threats facing the GBR in the Wet Tropics region. The other major threats are coastal development, shipping (and boating), recreational pressures, fishing/netting and climate change. Of these, climate change is the most difficult to address, with the potential to synergistically elevate the impacts of other threats. This makes it even more critical to address agricultural impacts to having a reasonable chance of protecting current values.
- Research and development of improved technologies (equivalent to A class or better) which are adoptable at scale are critical.
- Partnerships with industry and significantly increased public funding are crucial as much of the action needs to occur on private land, and some of the more significant changes are likely to have negative private benefits.
- Given Australia's need to compete in a global economy as well as the economy of scale challenges faced by smaller farmers (e.g. <100ha in sugar cane), the trend towards intensification and/or increasing farm size in sugar cane, grazing, cropping and horticulture is likely to continue. The 'small farm' issue (namely that costs and often adoption barriers pose more challenges on smaller than larger farms) is another serious constraint which needs further policy attention in terms of deciding whether/how to deal with it, either from a social welfare or environmental perspective.
- There remains uncertainty in some crucial aspects of the science associated with water quality, ecological responses and maintenance of values of the Reef. Estimates of the effectiveness of best management practices in terms of water quality benefits and costs still have a relatively low level of confidence.
- There is limited quantification of the benefits of restoring coastal ecosystems and floodplain function to catchment GBR ecosystems, however current conceptual understanding indicates these system functions are critical for restoring and protecting the receiving ecosystems of the GBR.
- Much greater levels of funding (particularly without much stronger targeting and accountability of funding spent to maintain benefits) will be required to achieve outcomes than are currently being allocated.

Overall, unparalleled levels of funding, a strong commitment to improving the science (especially integration with economics), the need to 'take action now whilst managing adaptively', and investing in an increasingly strategic and targeted fashion will be required if agricultural and coastal development impacts on the Wet Tropics catchment and marine ecosystems are to be managed. While many trajectories are possible, the following principles are likely to be needed to maintain some of the existing values of the marine ecosystems in an efficient and accountable manner.

- Specific and agreed performance goals and targets which may involve definition of an agreed cap on total pollutant discharges. This would need to be supported by improved conceptual understanding of the likely ecosystem health responses to a several pollutant reduction scenarios over varying timeframes.
- Clear articulation of rules, responsibilities and accountability of institutions to ensure that there is a clear pathway for achieving the agreed performance goals and targets, including public and timely reporting of successes and failures.
- Establishment of baseline nutrient discharges and development of appropriate metrics to enable industries (agricultural and urban) to respond to signals of change, and guide prioritisation of resource allocations.
- Application of well-considered and long term best practice policy approaches based on public and private net benefits. This is likely to require a mix of incentives, extension, research and underpinning regulations for different sectors.
- Long term constructive commitment of government, industry and environmental stakeholders to understand perspectives, respect differences and work collaboratively towards the agreed performance targets and goals.

From the perspective of protecting some of the World Heritage values of the GBR from agricultural and coastal development sources the vision for 2050, which cannot be restricted to the Wet Tropics region, it is important that the following factors will be well established and agreed between key stakeholders:

- Ecologically meaningful caps/limits on pollutant discharges for major constituents across major contributing land uses, including urban sources.
- Funding of monitoring and interpretation effort that is commensurate with the value of the World Heritage Area. This should research for development of improved technologies and innovative management practices and long-term commitment to monitoring and modelling programs to gauge progress and manage adaptively.
- A well- developed water quality trading scheme between agricultural and urban sources. The reason for a trading scheme is that substantial cost-savings can be made compared with other mechanisms. The large amount of funding that will be required to protect the GBR, and Australia's experience in developing trading schemes (e.g. water markets) make water quality trading seem a sensible approach to explore and learn from the experience of others (e.g. Lake Taupo in New Zealand).
- Continued efficient and world competitive agricultural industries, having navigated through a period of reform with appropriate social welfare policy which has helped in the structural adjustment process Institutional clarity and accountability for regulation through the Queensland and Australian Governments.
- Commitment to long term extension and knowledge brokering, communication, evaluation and reporting systems to capture the supporting information and outcomes of progress towards the vision.
- Initiatives that support synthesis of research and specifically considering how all contributing factors interact to enable assessment at a whole of landscape (paddock to reef) scale.

An incremental largely business as usual approach will not address the challenges facing the GBR.

The following section outlines the management approaches and strategies recommended to progress water quality improvement in the Wet Tropics region in the short term, however, in the context of the information above it is clear that new and large scale initiatives will be required in the longer term.

8. Implementation Plan

Implementation programs for the Wet Tropics WQIP over the next 5 years are described below and include a combination of direct on-ground actions and enabling activities. The programs required for directly reducing pollutant loads and restoring ecologically function are considered to be sufficiently different to present them separately; however, the actions come together in the basin-scale implementation plans. Funding to support the actions identified in the Implementation Plan has not been secured and will be sought from a range of sources including the Australian and Queensland governments.

8.1 Strategies for achieving pollutant load reductions

8.1.1 Actions for directly reducing pollutant loads

Based on available information, it is evident that it will be challenging to meet the 2018 Reef Plan targets and the longer term ecologically relevant targets with the current suite of agricultural management practices. Accordingly, extension and education programs and research and development to investigate innovative practices are critical for implementation of the WQIP over the next 5 to 10 years. However, as described in Section 7, the implications of these limitations to the health of freshwater, coastal and marine ecosystems must be considered seriously. Considerable trade-offs will be required between the level of management change that is considered to be acceptable politically and by the community, and the desire to maintain the values of the receiving environments including the GBR. Restoration of ecological functions in the floodplain and coastal ecosystems have a role in reducing pollutant loads; however, the likely benefits of these restoration activities are yet to be quantified and is a knowledge gap in this WQIP.

To inform the choice of management options, we have collated knowledge about the best choice of management practices for improving water quality outcomes in the Wet Tropics region. These are translated into focus areas for each of the key land uses in the region in Table 8.1 and largely draw on information collated in Sing and Barron (2014) and Gunn (2014). Prioritisation of actions within each basin has been informed by the results from the Water Quality Risk Assessment (Waterhouse et al., 2014) shown in Table 3.5. The approach for implementation is supported by a number of enabling activities outlined below.

Table 8.1. Strategies for progressing achievement of pollutant load reduction targets in the Wet Tropics region. These are summarised from Section 3.4.

	Focus Actions			
Land use / Strategy	**Dissolved Inorganic Nitrogen**	**PSII Herbicides**	**Suspended Sediment / Particulate Nutrients**	**Approach for Implementation**
Sugar cane ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices.* *Research and development to support innovation in management practice* ***Priority Basins:*** **Russell-Mulgrave** **Johnstone** **Tully-Murray** **Herbert**	Very High Priority 1. Adoption of Smartcane BMP framework as industry minimum standard (and minimum legislative standards). 2. Optimise fertiliser (N) application to reduce N surplus and increase nitrogen use efficiency. Target the amount used and timing, and to a lesser extent its placement. 3. Variable rate application through identification of georeferenced soil zones (Precision Agriculture) to reflect block yields and soil characteristics. 4. Encourage adoption of whole farm management systems amongst farmers and contractors.	Very High Priority 1. Target timing of herbicide application (no application within 30 days of wet season commencement – implies greater use of forecasting). 2. Residual use in plant crops and ratoons. 3. Banded spray applications. 4. Hooded sprayers. 5. Row spacing	Low Priority 1. Target controlled traffic farming. 2. Target best practice drainage management.	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (georeferenced soil zones, whole farm management systems). • Encourage farmers to move along a path where initially they use 6ES based on 120% of district yield, then with-in mill area districts, followed by farm yields, block yields then with-in block yields. This approach would be combined with the impact on yield of time of harvest, stage in crop cycle, proximity to the start of the wet season and age of crop. • Training course of risks of N losses and the management options. Targeting larger cane farms in conjunction with one-on-one extension. Target 170 management units with farms greater than 200 ha which covers 60% of the land under cane. • Extension to encourage tailored nutrient rates for high risk locations, time of the year, late harvested crops and parts of the crop cycle. • Provision of incentives supported by long-term management agreements (until improved technology improves practices to become profitable in their own right). • Auditing and reporting program to ensure compliance with management agreements. • R&D into slow release fertilisers, innovative fertiliser reduction schemes.

Land use / Strategy	Dissolved Inorganic Nitrogen	Focus Actions PSII Herbicides	Suspended Sediment / Particulate Nutrients	Approach for Implementation
Bananas ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Russell-Mulgrave** **Johnstone** **Tully-Murray**	High Priority 1. Optimise fertiliser application through fertigation. 2. Use of slow release fertilisers to complement fertigation. 3. Use of permanent beds and block contouring 4. Liaison with extension officers and farm consultants regarding recommended nutrient application rates	Limited use 1. Best practice inter row maintenance	Moderate Priority 1. Target permanent beds, contour banks and improved maintenance of the inter row	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides.
Mixed cropping and other horticulture **Strategy:** *Research and development to address knowledge gaps in terms of practices, practice effectiveness and costs* ***Priority Basins:*** **Barron**	Low Priority	Use depends on crop	Moderate Priority 1. Target contour banks, minimum tillage, controlled traffic and grassed headlands as a package of works.	• Use extension to promote sediment management as a package of practices that complement each other and support this by finanical incentives.
Dairy ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Barron**	Low Priority 1. Use of slow release fertilisers.		Low Priority 1. Fencing to exclude access to riparian areas and stream banks and installation of off-stream watering sites.	
Grazing ***Strategy:*** *Incentive and extension programs to achieve adoption of improved practices* ***Priority Basins:*** **Herbert**	Low Priority	Limited use	High Priority Key sources: Streambank and hillslope erosion 1. Retention of ground cover at the end of dry season. 2. Stocking rates consistent with regional benchmarks and property characteristics. 3. Strategies implemented to recover land in poor or very poor condition and target erosion hotspots.	• Work with owners of properties that have been shown to have low levels of ground cover over the last ten years to reduce stocking rates which should in the longer term produce higher returns for those graziers. • Training course on soil health. • Training course on best practice road and fence construction.

Land use / Strategy	Dissolved Inorganic Nitrogen	Focus Actions PSII Herbicides	Suspended Sediment / Particulate Nutrients	Approach for Implementation
			4. Fencing off rilled areas, gullies, riparian and sodic soil areas. 5. Best practice road maintenance and construction, and fence line clearing.	
Urban **Strategy:** *Adoption of improved practices in urban development* *Priority Basins:* **Barron** **Russell-Mulgrave**	Moderate Priority 1. Continue to investigate options for sewage effluent reuse.	Low Priority	Moderate priority *Developing areas* 1. Erosion and sediment control 2. Water Sensitive Urban Design *Mature urban areas* 3. Stormwater management to reduce peak flow intensity through dispersal areas.	• Consultation with local government to target soil erosion and subsequent movement of sediment to waterways during the development phase, particularly on sloping sites as well as floodplains and flat sites especially in close proximity to waterways. • Focus on new developments due to large costs associated with retrofitting. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.
Other land uses				
Disused mine sites in the Upper Herbert *Priority Basins:* **Herbert**			High priority	These actions require further consideration and discussion with relevant stakeholders in 2015.

Existing programs in the Wet Tropics

A number of initiatives are already in place, and some of these have funding support for up to 3 years. The key programs are summarised in Table 8.2. Importantly, there are no long term funding initiatives to support this Implementation Strategy beyond 2019 and a majority of the funding is only committed to 2016.

Table 8.2. Summary of the key existing programs in the Wet Tropics region relevant to directly reducing pollutant loads.

Program	Type	Funding commitment	Description
Reef Programme Water Quality Grants	Positive incentives	~$14M 2013-2016	Provides funds to farmers to facilitate best management farming practices to reduce the amount of nutrients, pesticides and sediments leaving farmland (particularly sugar cane and to a lesser extent, grazing, horticulture and multicrops) and impacting on reef water quality. The grants scheme and extension programme are administered by Terrain and government, industry and research partners. Continues investment provided through Reef Rescue 2008-2013. The roll-out of these incentives will be continuously improved based on the lessons from each successive round.
Reef Programme Training and Extension for sugar cane	Training and extension	$1.811M 2014-2016	The Training and Extension Program for cane is coordinated by Terrain NRM and will be delivered by contracted Cooperative of representatives from Canegrowers and the Productivity Boards in the region. Extension Officers are required to work with all farmers that have received water quality grants under the Reef Programme to assess their extension and training needs. This will include either checking and reviewing existing Nutrient Management Plans (NMP) and Integrated Weed Management Plans (IWMP) that are required to secure the grants, against Risk Assessment criteria defined by Terrain NRM in collaboration with industry, or helping them to develop new plans. Extension Officers will meet with farmers at least three times to: 1) assess training needs, 2) work to develop NMP/IWMs and 3) after completion of project to do follow up practice change survey and verify implementation of the agreed plans. There are also minimum numbers of farmers that have not received water quality grants that will be targeted to assess training and extension needs and help to develop NMPs or participate in future grants opportunities. Extension and Training data will be collected from all farmers participating in the program. This will include farm practice data. This program will form of the basis of the extension and training activities identified in Table 7.1 and 7.2, and is designed to target a minimum of 727 growers[23]. Minimum targets for the numbers of growers engaged in the Wet Tropics Training and Extension Programme are incorporated into Table 7.2.
Reef Trust Reverse Auction in sugar cane	Innovation and technology change Positive Incentives	$5M 2014-2019	A market based completive tender (or reverse auction) is being used to allocate funds to farmers. Applicants are to provide a tender price, an amount that they will accept to increase their nitrogen efficiency per hectare. If successful they will enter into a contract with Terrain to say they will

[23] As specified in the Terrain NRM Invitation to Tender for the supply of training and extension to sugarcane growers in Queensland Wet Tropics as a component of the Wet Tropics Reef Water Quality Programme, August 2014.

Program	Type	Funding commitment	Description
			reduce nitrogen inputs by the amount they calculated and then they will be paid annually ($/ha) to deliver on this. There are minimum practice standards that must be met within the first year of the project, such as sub-surface fertiliser application and soil testing. Lessons from this program will also be incorporated into broader incentive mechanism design.
Reef Programme Game Changer projects	Innovation and technology change Positive Incentives	~$745,000 2013-2016	The project seeks to support sugarcane farmers across three regions (Wet Tropics, Burdekin and Mackay/Whitsunday) to develop and test 'next generation' practices to reduce residual nutrient and herbicide loads running off farm. The project is supporting growers to develop crop, nutrient and weed management plans. Selected projects will also undertake rainfall simulation experiments and economic analysis.
Project Catalyst	Innovation and technology change	~$120,000 per year Annual commitments	Project Catalyst is a partnership between WWF and Cocoa Cola - delivered through Reef Catchments. The project aims to support innovative practices with sugar cane farmer clusters (4 in Wet Tropics), involving formal management practice trials (including economic analysis, rainfall simulation etc).
Wet Tropics Agriculture Innovation Program	Innovation and technology change	~$748,000 2014-2017	The program is relevant to all primary production with a current focus on the sugar cane, banana, multi-cropping, dairy and grazing industries. Program objectives: - Develop, and secure broad regional buy-in for a region-wide Innovation Strategy; - Support a range of farmer-led innovation projects, providing targeted assistance aimed at progressing them through the stages of the Innovation Cycle; - Facilitate broad-scale communication about the outcomes of the innovation projects (e.g. case studies, field days, audio-visual products such as you-tube videos, an Innovation Forum); - To establish and maintain a region-wide Innovation Network; and Identify and where possible address the constraints to innovation at the regional, state and national level. Examples of initiatives under this project include a soil health extension program, training courses to promote farm sustainability (Re-Gen Ag), and landholder innovation grants (Reef Programme). To date, an assessment of the scope and nature of farmer-led innovation across the region has been conducted and a database of 'Innovative' farmers generated. An extensive database of relevant local and international literature on regenerative agricultural practices (predominantly peer reviewed) has also been developed. In combination, this information is being used to inform the discourse on the trialing and expedited broad scale adoption of Innovative practices across industries.

8.1.2 Strategies for restoring catchment waterways and ecological function of coastal ecosystems

The first step in determining management actions for maintaining or restoring freshwater ecosystem health, catchment waterways and restoring ecological function in coastal ecosystems in the Wet Tropics region is to collate knowledge about values and threats. This information is presented in Section 5.1, and is supported by a clear and comprehensive management framework (Figure 5.2). The most obvious management action for addressing water quality issues in these ecosystems is the application of the Water Quality Guidelines defined under the EPP (Water) and the recently scheduled EVs and WQOs for the region. This process is already well established in the region and incorporated into relevant policy and planning documents. Identification of actions to address issues associated with ecological function of coastal ecosystems is more challenging, and many of the actions required in the next 3 to 5 years are associated with planning to maximise the impact of any resource allocation, and quantification of the ecological, social and economic benefits of restoration options. Section 5.3 outlined an approach for progressing this for the Wet Tropics region for the next 5 years.

8.2 Basin–scale Implementation Plans for the Wet Tropics

This section provides more detail on the strategies to be employed in each Basin in the Wet Tropics region. It is guided by the information summarised in Section 8.1, and Table 8.1 in particular. Management practice options are also guided by data on the likelihood of management practice adoption (area of C class practices and farm size), the priorities identified in the relative risk assessment, the regionally specific pollutant load reduction targets and the INFFER analysis.

However, it should be noted that several of the basins (catchments) have very active Catchment and or Landcare Groups and existing Catchment level Management Plans (and other detailed site specific Plans) that community and Governments have invested significant effort and resources into developing and implementing (See Table 8.3 for some examples of these Plans). The WQIP largely presents options at the strategic scale and the detail of sites and specific activities is captured by these catchment and site-specific Plans that community has developed and invested a great deal of knowledge and time in. There are also several Indigenous Protected Areas throughout the region (including Eastern Kuku Yalangi, Mandingalby-Yidinji, Girringun) that have developed or are developing Management Plans that also address management of country. Any specific basin actions should take these existing plans and recommendations into account before progressing.

Table 8.3. Examples of basin plans that already exist in the Wet Tropics region that should be consulted further prior to implementing any more detailed basin-specific initiatives in association with this WQIP. Additional Plans also exist for the region (Tully, Herbert etc.).

Basin	Plan	Year Developed	Updated	Detail
Barron	Technical Report on Rehabilitation needs. A report prepared by the NQ Joint Board to facilitate coordinated catchment management in the Barron Catchment.	1997	N/A	Strategic overview giving technical details about the landscape including soils, geology, water resources, flora and fauna and identifies catchment needs and priorities. Foundational information for the Barron River Catchment Management Plan.
	Barron River Catchment Management Plan	2004	2010	Presents an overview of the catchment, the management issues and the strategies to address these issues. Influence policy, riparian repair, council planning, habitat restoration, education, farming practices. Provides strategies and actions for priority issues and areas for the Barron Catchment.
Sub-Plan	Rocky Creek Reserves Precinct Management Plan	2003	N/A	Provides a framework for enhancing and integrating the management of the parcels of reserve land remaining in this environmentally and culturally significant area. Tableland Regional Council and community continue to undertake work in Rocky Creek and Barney Springs in particular.

Basin	Plan	Year Developed	Updated	Detail
				Specific objectives include: • Conserving the significant environmental and cultural assets of the area particularly associated with the natural springs • Restoring degraded lands • Integrating management and land use planning • Maximising economic & social benefits to the local community
Sub-project	The Green Corridor Project	2005		Initial 5 year project that provided foundation for work that is still continuing and will enhance the physical stability of the river banks, enhance biodiversity, by re-establishing native habitat both within and along the river and improve water quality, both within the Barron River itself and in the Great Barrier Reef Lagoon. To date more than 110,000 trees have been planted.
Sub-project	Barron Delta Community Project	2010-2013		Project had strong Indigenous collaboration and increased the level of community involvement in caring for the delta environment and increased the extent of native habitat of the delta, managed weeds and improved the condition and connectivity of habitats and landscape over 35 hectares of the delta. This work is still continuing and will help make the delta more resilient to current and future threats such as sea level rise, storm surges and more intense cyclones.
Mulgrave	Mulgrave River Management Action Plan	2001		Provides a prioritisation matrix for site rehabilitation that maximises sustainable management of the Mulgrave River. Report documents stages of the project including - biophysical setting, approach to take, identification of issues, geomorphological assessment of the river, field studies
Sub-project	**“ Corridor enhancement between sugar-cane lands, streams and the World Heritage areas in Mulgrave Catchment- Wet Tropics.”**	2012		This 5-year project involves biodiverse plantings on the Mulgrave River in larger degraded areas, riparian gaps & wetland fringes, complemented by control of threatening hymenachne and pond-apple populations.
Johnstone	Johnstone River Catchment Management Strategy Johnstone Rivers Management Plan	1994	2013	State Government pilot project for planning for Integrated Catchment management (ICM) and provided strategies for land management, water management, riverine management, habitat management. Identifies a number of key issues and provides a number of recommendations to deal with identified issues.
	South Johnstone River Management Action Plan	2004		Prioritises stream rehabilitation works; developed a 3 stage evaluation method for 31 reaches of the river and tributaries.

Basin	Plan	Year Developed	Updated	Detail
				Provides a detailed description of actions in specific areas.
	Liverpool Creek River Management Action Plan	2000		Outlines a strategic approach to the management of the South Liverpool Creek Prioritises stream rehabilitation works; developed a 3 stage evaluation method for 46 reaches of the Liverpool Creek system Provides a detailed description of actions in specific areas.

The basis for the Management Actions and targets for sugar cane in the Implementation Plans for each basin (Table 8.7 to 8.15) is summarised in Table 8.4 for DIN, and Table 8.5 for PSII herbicides. An overall summary for cane is provided in Table 8.6. The results of the INFFER assessment clearly indicate that the most cost effective option is to invest in a shift to All B practices. The issue is the shortfall in the progress towards the DIN reduction targets, and therefore, the original approach was to aim for All A practices in most basins to maximise water quality outcomes. Accordingly, **the costing presented in Table 8.6 is based on the INFFER analysis for an 'All A practice' scenario. Further consultation with the sugar cane industry representatives and technical experts after the INFFER analysis was completed has led to an agreement to aim for a more realistic and cost effective target of a minimum of All B practices across the region, encouraging continuous improvement through training and extension programs and supporting R&D.** An example of the targets that addresses these issues is: 100% of sugar cane area in the Mulgrave basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018. **The costs shown in Table 8.6 and the basin implementation tables are based on All A scenarios and are therefore higher than what should be required for an 'All B practice' scenario where lower incentive payments should be required.**

Priorities are also identified among the basins. Six basins are equally very high priority for action to reduce pollutant loads to the GBR. These basins are: Johnstone, Tully/Murray, Herbert and Russell/Mulgrave. Basin-specific social and economic characteristics related to current management practice adoption, farm size and therefore the economic feasibility of practice change influence the feasibility of reducing pollutant load reductions in each basin. **Based on this, the Tully-Murray and Johnstone basins currently appear to be the highest priority basins for practical targeting investment in sugar cane practice improvement.**

Promoting a widespread shift to A class practices across the region raises concerns related to the fact that A class practices are typically not underpinned by sufficient evidence of water quality and productivity gains. Other factors that contribute to the aspirational nature of an All A practice target include the scope of current funding versus predicted costs, knowledge of barriers to adoption, and historic patterns of participation in incentive programs in the region. Regional experience indicates that a proportion of land managers, estimated at 10 to 20% depending on the industry and circumstances, are unlikely to shift to improved management practices (Reef Rescue adoption database; Marsden Jacob Associates, 2013). The impact of this is entirely dependent on the characteristics of these landholders in terms of property size and level of practices. Terrain NRM is currently undertaking surveys to estimate the scope of these issues in the region. Despite these limitations it is important to identify that based on current knowledge of relationships between pollutant loads, water quality conditions and ecosystem health, these targets will not be sufficient to meet the long term goal of the Reef Plan, and this is an issue that needs to be addressed at the GBR wide scale.

For all industries other than sugar cane, the relevant Reef Plan target region-wide is applied which is that 90% of area of each industry in each basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum. Basin specific adoption data is currently not available so it is not possible to specify area targets for all sectors at this time. However, basin-specific targets have been proposed where additional information is available to provide more reliable estimates.

As stated earlier, it is recognised that the definitions (and hence, outcomes) of the industry ABCD classes will change as the water quality benefits and economic viability of new and innovative practices are proven and accepted over time. Therefore, the estimate of pollutant load reductions from practice shifts presented in the WQIP are essentially static, and do not take into account improvements in the magnitude of water quality benefits associated with each practice class over the 5 year period of the Implementation Plan (2018 to coincide with Reef Plan targets), towards the ecologically relevant targets (2035, i.e. 20 years from now) and the Reef 2050 Long Term Sustainability Plan (2050, i.e. 35 years from now). Achievement of the ecologically relevant targets for pollutant load reductions can be viewed as a trajectory from baseline estimated in 2008-09, 2013 load estimates, Reef Plan targets by 2018 and ecologically relevant targets by 2035.

The management targets related to protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems are also drawn from the Reef Plan 2013 targets. Basin specific planning has been conducted in the past, and examples of possible actions and projects are included in the profiles for each basin in the region. These examples, along with the information from the new spatial planning framework described in Section 5, will form the basis to a series of community workshops planned in 2015 to establish a set of priority actions and projects for 'system repair' in the Wet Tropics region.

Table 8.4. Summary of key characteristics that guide the management approach reduction of DIN loads from sugar cane in the Wet Tropics basins. The dark green highlighted cells indicate that the reduction meets the proposed Ecologically Relevant Target reduction, light green highlighted cells indicate that the reduction meets the Reef Plan target reduction. The investment ranking (1 = highest, 3 = lowest) is based on consideration of farm size, total area, strategy and management approach. Note: ERT = Ecologically Relevant Target; DIN = Dissolved Inorganic Nitrogen

Basin	Farm size: greatest proportion farmer	Total area cane (ha) (RR adoption data)	Proportion of basin managed at C class practice (based on ha)*	Total area (ha) of C practices in basin	Pollutant load reduction scenarios for DIN Reef Plan target = 50%				Meet Reef Plan DIN Target if min. B class	Meet ERT DIN Target if min. B class	Strategy	Management Approach	Invest priority / $ ranking
					ERT DIN	All A	50% AB	All B					
Daintree-Mossman	Small: 40% Med: 37%	5,750	82%	4,715	50	23	20	17	N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Medium 3
Barron	Small: 46%	3,975	53%	2,107	50	6	5	4	N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Low 3
Russell[1]	Small	5,407	85%	4,596	70	33	26	20	N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High 2
Mulgrave		6,991	57%	3,985					N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High 2
Johnstone	Small: 62%	15,668	66%	10,341	80	13	11	9	N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Very High 1
Tully[2]	Large: 41%	26,640	60%	15,984	80	18	14	11	N	N	Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Very High 1
Murray					80	45	37	29					
Herbert	Small: 38% Med: 35%	50,888	41%	20,864	80	85	72	58	**Y**	Only if All A	Minimum All B	Moderate Incentives, High extension & training	High 1
Total		**115,320**		**62,592**		**28**	**24**	**19**	**N**	**N**			

Note: [1] Parts of the analysis are conducted for the combined Russell-Mulgrave catchment. [2] Parts of the analysis are conducted for the combined Tully-Murray catchment

Table 8.5. Summary of key characteristics that guide the management approach reduction of PSII herbicide loads from sugar cane in the Wet Tropics basins. The dark green highlighted cells indicate that the reduction meets the proposed Ecologically Relevant Target reduction, light green highlighted cells indicate that the reduction meets the Reef Plan target reduction. The investment ranking (1 = highest, 3 = lowest) is based on consideration of farm size, total area, strategy and management approach. Note: ERT = Ecologically Relevant Target; PSII = PSII herbicide.

Basin	Farm size: greatest proportion farmer	Total area cane (ha) (RR adoption data)	Proportion of basin managed at C class practice (based on ha)*	Total area (ha) of C practices in basin	Pollutant load reduction scenarios for PSII herbicides Reef Plan target = 60%				Meet Reef Plan PSII Target if min. B class	Meet ERT PSII Target if min. B class	Strategy	Management Approach	Invest priority / $ ranking
					ERT PSII	All A	50% AB	All B					
Daintree-Mossman	Small: 40% Med: 37%	5,750	82%	4,715	0	98	82	65	**Y**	**Y**	Minimum All B	No Incentives High extension & training	Low 3
Barron	Small: 46%	3,975	53%	2,107	0	34	27	21	N	**Y**	Minimum All B	No Incentives Moderate extension & training	Low 3
Russell[1]	Small	5,407	85%	4,596	82	99	80	64	**Y**	Only if All A	Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	Med 2
Mulgrave		6,991	57%	3,985									
Johnstone	Small: 62%	15,668	66%	10,341	83	96	81	65	**Y**	Only if All A	Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	High 2
Tully[2]	Large: 41%	26,640	60%	15,984	73	99	82	66	**Y**	Min. 50A:50B required	Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	High 1
Murray					70	99	82	66					
Herbert	Small: 38% Med: 35%	50,888	41%	20,864	90	97	78	60	**Y**	Only if All A	Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	High 1
Total		**115,320**		**62,592**		**95**	**79**	**63**	**Y**				

Note: [1] Parts of the analysis are conducted for the combined Russell-Mulgrave catchment. [2] Parts of the analysis are conducted for the combined Tully-Murray catchment

Table 8.6. Summary of management approaches, estimated costs and extension effort for DIN and PSII herbicide load reductions in sugar cane the Wet Tropics region.

Basin	Priority /DIN Adoption Strategy	DIN Management Approach	PSII Adoption Strategy / Priority	PSII Management Approach	Shift to All B practices ($M/yr)			Extension effort to 2016				
					Upfront cost over 5 yrs	Annual mainten-ance cost	BCR	No. of growers	Growers receiving grants	Growers DIN priority	Minimum T&D delivery outcomes	Proportion of growers targeted
Daintree-Mossman	Medium Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Low Minimum All B	No Incentives, High extension & training	0.3	0.3	1.20	68	19	22	41	60%
Barron	Low Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Low Minimum All B	No Incentives, Moderate extension & training	0.3	0.3	0.3	60	18	1	19	32%
Russell[1]	High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	Medium Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	0.9	0.9	0.8	283	100	71	171	60%
Mulgrave	High Minimum All B; aim for at least 25% A	High Incentives, High extension & training										
Johnstone	Very High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	0.9	0.9	3.10	172	89	30	119	69%
Tully-Murray	Very High Minimum All B; aim for at least 25% A	High Incentives, High extension & training	High Minimum All B; aim for at least 25% A	Moderate Incentives, High extension & training	1.2	1.2	1.27	200	71	66	137	69%
Herbert	High All A desirable; aim for min. 50% A	Moderate Incentives, High extension & training	High All A desirable; aim for min. 50% A	Moderate Incentives, High extension & training	2.9	2.9	0.22	580	156	84	240	41%
Total								1,363	453	274	727	53%

Note: [1] Parts of the analysis are conducted for the combined Russell-Mulgrave catchment.

Table 8.7. Daintree Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (Relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Low***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Daintree basin is managed within A and B class practices by 2018. These levels should then be maintained beyond 2018 as a minimum.** Based on 2013 figures, the minimum area where the practice shift is required in the combined Daintree-Mossman catchment (total area of cane 5,750 ha) is 4,700ha.	• **DIN (Medium):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (Low):** Extension programs to shift total area of cane to a minimum of B class practices. *See Table 8.1 for examples.* ***Management approach: No incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Daintree-Mossman catchment: Minimum of 41 growers (60%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Daintree-Mossman catchment is estimated at $0.3M upfront over 5 years, then $0.3M/yr maintenance costs	Terrain Canegrowers Mossman Agricultural Services SRA DAFF Research providers	High
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will	Total allocation across the region: $100,000 per annum. Note. The	Terrain Development Industry Douglas Shire	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (Relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
		include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	FNQROC	
Other land uses	**Wet grazing, Horticulture**	• Land managers adopt priority BMPs in wet grazing and all horticultural crops consistent with ABCD Framework. • Undertake extension programme to maximise adoption of priority BMPs through short courses and demonstrations. • Facilitate external incentive programs aiding landholders in the implementation of priority BMPs.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for all agricultural industries except sugar cane.*		Low
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Protect***					
Riparian vegetation	**The extent of riparian vegetation is increased by 2018.** *As identified in the Douglas WQIP – Mossman, Mowbray, Upper Daintree & Saltwater Catchments*	• Maintain restoration programs with active partnerships with Douglas Shire Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	DSC, Terrain, Catchment community	Moderate

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (Relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.** *Mossman, Mowbray, Daintree & Saltwater Catchments*	Example: • Priority planning and implementation for replacement/modification of 32 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	TMR, DSC, Individual landholders	Low

Table 8.8. Mossman Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Low***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Mossman basin is managed within A and B class practices by 2018. These levels should then be maintained beyond 2018 as a minimum.** Based on 2013 figures, the minimum area where the practice shift is required in the combined Daintree-Mossman catchment (total area of cane 5,750 ha) is 4,700ha.	• **DIN (Medium):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 7.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (Low):** Extension programs to shift total area of cane to a minimum of B class practices. *See Table 7.1 for examples.* ***Management approach: No incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Daintree-Mossman catchment: Minimum of 41 growers (60%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Daintree-Mossman catchment is estimated at $0.3M upfront over 5 years, then $0.3M/yr maintenance costs	Terrain Canegrowers Mossman Agricultural Services SRA DAFF Research providers	High
Bananas	**90% of banana area in the Mossman basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding.*	Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	Basin specific adoption data is currently not available.	• Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Maintain this level as a minimum.*		
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain Development Industry Douglas Shire FNQROC	Low
Other land uses	**Wet grazing, Horticulture**	• Land managers adopt priority BMPs in wet grazing and all horticultural crops consistent with ABCD Framework. • Undertake extension programme to maximise adoption of priority BMPs through short courses and demonstrations.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for all agricultural*		Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
		• Facilitate external incentive programs aiding landholders in the implementation of priority BMPs.	*industries except sugar cane.*		
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Adapt***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.** *As identified in the Douglas WQIP – Mossman, Mowbray, Upper Daintree & Saltwater Catchments*	• Maintain restoration programs with active partnerships with Douglas Shire Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	DSC, Terrain, Catchment community	Low
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.** *Mossman, Mowbray, Daintree & Saltwater Catchments*	Example: • Priority planning and implementation for replacement/modification of 19 priority fish barriers (culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	TMR, DSC, Individual landholders	Moderate

Table 8.9. Barron Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Low***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Barron basin is managed within A and B class practices by 2018. These levels should then be maintained beyond 2018 as a minimum.** Based on 2013 figures, the minimum area where the practice shift is required in the Barron basin (total area of cane 3,975ha) is 2,100ha.	• **DIN (Low):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (Low):** Extension programs to shift total area of cane to a minimum of B class practices. *See Table 8.1 for examples.* ***Management approach: No incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016: Minimum of 19 growers (~30%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost is estimated at $0.3M upfront over 5 years, then $0.3M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Barron basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding.*	Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	Basin specific adoption data is currently not available.	• Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Maintain this level as a minimum.*		
Mixed Cropping	**90% of mixed cropping area in the Barron basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** *Basin specific adoption data is currently not available.*	• Extension program to support shifts to B class practice, focusing on sediment management.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain	Moderate
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cairns Regional Council FNQROC	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Other land uses	Cairns Port	• Complies with licensing requirements. *Cairns Port info from EIS re dredging- available in October 2014*	*In-kind support only; not within the scope of the WQIP.*	Ports North	Low
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: By area Adapt; other MO to Protect, Restore and Maintain are included in some sub-catchments***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cairns City Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cairns Regional Council, Terrain, Catchment community	Low to Moderate
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	Example: • Priority planning and implementation for replacement/modification of 2 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cairns Regional Council, Individual landholders	Moderate

Table 8.10. Mulgrave Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Mulgrave basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the Mulgrave basin (total area of cane 6,991ha) is 4,000ha.	• **DIN (High):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (Medium):** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Russell-Mulgrave catchment: Minimum of 171 growers (~60%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Russell-Mulgrave catchment is estimated at $0.9M upfront over 5 years, then $0.9M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Mulgrave basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation,	*Regional estimate will be provided based on level of investment in Reef*	Terrain	High

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	These levels should then be maintained beyond 2018 as a minimum. *Basin specific adoption data is currently not available.*	permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Rescue 1 funding. Maintain this level as a minimum.*		
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cairns Regional Council FNQROC	Moderate
Other land uses	***Horticulture- other tree crops*: 90% of area in the Mulgrave basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should**	• Current knowledge gap.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for*	GrowCom, Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	then be maintained beyond 2018 as a minimum.		*all agricultural industries except sugar cane.*		
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Maintain & Restore***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cairns City Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cairns City Council, Terrain, Catchment community	Moderate
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.** *Mossman, Mowbray, Daintree & Saltwater Catchments*	Example • Priority planning and implementation for replacement/modification of 17 priority fish barriers in the Mulgrave/Russell (culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cairns City Council, Individual landholders	Moderate

Table 8.11. Russell Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Russell basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the Russell basin (total area of cane 5,407ha) is 4,600ha.	• **DIN (High):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (Medium):** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Russell-Mulgrave catchment: Minimum of 171 growers (~60%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Russell-Mulgrave catchment is estimated at $0.9M upfront over 5 years, then $0.9M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Russell basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation,	*Regional estimate will be provided based on level of investment in Reef*	Terrain	High

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	These levels should then be maintained beyond 2018 as a minimum. *Basin specific adoption data is currently not available.*	permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Rescue 1 funding. Maintain this level as a minimum.*		
Urban	As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cairns City Council Development industry	Low
Other land uses	***Horticulture- other tree crops*: 90% of area in the Russell basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should**	• Current knowledge gap.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for*	GrowCom, Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	then be maintained beyond 2018 as a minimum.		*all agricultural industries except sugar cane.*		
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Adapt, Restore and Maintain***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cairns City Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cairns City Council, Terrain, Catchment community	Moderate
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	Example: • Priority planning and implementation for replacement/modification of 32 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cairns City Council, Individual landholders	Moderate

Table 8.12. Johnstone Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Very High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Johnstone basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the Johnstone basin (total area of cane 15,668ha) is 11,000ha.	• **DIN (Very High):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (High):** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the Johnstone basin: Minimum of 119 growers (~70%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits.	Based on an All B class practice scenario, the cost in the Johnstone basin is estimated at $0.9M upfront over 5 years, then $0.9M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Johnstone basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding.*	Terrain	High

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	Basin specific adoption data is currently not available.	• Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Maintain this level as a minimum.*		
Dairy	**90% of dairy area in the Johnstone basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** *Basin specific adoption data is currently not available.*	• Extension program to support shifts to B class practice. • Continued R&D into slow release fertilisers, innovative fertiliser reduction schemes.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain	Low
Mixed Cropping	**90% of mixed cropping area in the Johnstone basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** *Basin specific adoption data is currently not available.*	• Extension program to support shifts to B class practice, focusing on sediment management.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain	Low
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cassowary Coast Council Development industry FNQROC	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
		• Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.			
Other land uses	Port of Mourilyan	• Complies with licensing requirements.	*In-kind support only; not within the scope of the WQIP.*	Ports North	Low
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Protect, Restore, Maintain and Adapt (Adapt largely in coastal floodplain area)***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cassowary Coast Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cassowary Coast Council, Terrain, Catchment community	Low to Moderate
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	• Priority planning and implementation for replacement/modification of 10 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cassowary Coast Council, Individual landholders	Moderate

Table 8.13. Tully Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Very High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Tully basin is managed within A and B class practices by 2018, with a minimum of 50% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the combined Tully-Murray catchment (total area of cane 26,640ha) is 16,000ha.	• **DIN (Very High):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides (High):** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Tully-Murray catchment: Minimum of 137 growers (~70%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Tully-Murray catchment is estimated at $1.2M upfront over 5 years, then $1.2M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Tully basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation,	*Regional estimate will be provided based on level of investment in Reef*	Terrain	High

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	These levels should then be maintained beyond 2018 as a minimum. *Basin specific adoption data is currently not available.*	permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Rescue 1 funding. Maintain this level as a minimum.*		
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cassowary Coast Council Development industry FNQROC	Low
Other land uses	**Other horticulture: 90% of area in the Tully basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	Current knowledge gap.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for*	GrowCom, Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
			all agricultural industries except sugar cane.		
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Protect, Restore, Maintain and Adapt (Adapt largely in coastal floodplain area)***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cassowary Coast Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cassowary Coast Council, Terrain, Catchment community	Low
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	• Priority planning and implementation for replacement/modification of 6 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cassowary Coast Council Individual landholders	Moderate

Table 8.14. Murray Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Very High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Murray basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the combined Tully-Murray catchment (total area of cane 26,640ha) is 16,000ha.	• **DIN:** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: High incentives, high extension and training*** • **PSII herbicides:** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the combined Tully-Murray catchment: Minimum of 137 growers (~70%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the combined Tully-Murray catchment is estimated at $1.2M upfront over 5 years, then $1.2M/yr maintenance costs	Terrain Canegrowers Productivity Board SRA DAFF Research providers	High
Bananas	**90% of banana area in the Murray basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation,	*Regional estimate will be provided based on level of investment in Reef*	Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	These levels should then be maintained beyond 2018 as a minimum. *Basin specific adoption data is currently not available.*	permanent beds, contouring). Target by farm size. • Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Rescue 1 funding. Maintain this level as a minimum.*		
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.	Terrain and Cassowary Coast Council Development industry	Low
Other land uses	**Other horticulture: 90% of area in the Murray basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	Current knowledge gap.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for*	GrowCom, Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
			all agricultural industries except sugar cane.		
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Protect, Restore, Maintain and Adapt (Adapt largely in coastal floodplain area)***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Cassowary Coast Council, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Cassowary Coast Council, Terrain, Catchment community	Low
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	• Priority planning and implementation for replacement/modification of 3 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Cassowary Coast Council, Individual landholders	Moderate

Table 8.15. Herbert Basin Implementation Plan.

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
Directly reducing pollutant loads ***Relative regional priority: Very High***					
Primary Land uses					
Sugar cane	**100% of sugar cane area in the Herbert basin is managed within A and B class practices by 2018, with a minimum of 25% of cane area managed within A class practices. The proportion of A class practices should continue to increase beyond 2018.** Based on 2013 figures, the minimum area where the practice shift is required in the Herbert basin (total area of cane 50,888ha) is 21,000ha.	• **DIN (High):** Incentives and extension programs to shift the total area of cane to the highest possible standard that has been proven to achieve the greatest water quality benefit and is economically viable. *See Table 8.1 for examples.* These practices will inevitably change (improve) over time with R&D and industry support. ***Management approach: Moderate incentives, high extension and training*** • **PSII herbicides (Moderate):** Extension programs to shift total area of cane to a minimum of B class practices, aiming for at least 50% in A class practices. *See Table 8.1 for examples.* ***Management approach: Moderate incentives, high extension and training*** • There will be no areas remaining in C or D class practice management. • Extension effort allocated to 2016 in the Herbert basin: Minimum of 240 growers (~40%) engaged. • Research and engagement with industry to assess costs and effectiveness of innovative and emerging management practices to maximise water quality benefits. Facilitated by the Wet Tropics Agricultural Innovation Program.	Based on an All B class practice scenario, the cost in the Herbert basin is estimated at $2.9M upfront over 5 years, then $2.9M/yr maintenance costs	Terrain Canegrowers HCPSL SRA DAFF Research providers	High
Bananas	**90% of banana area in the Herbert basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	• Extension program to support shifts to B practice; long-term incentive program to support shift to A practice (equipment for fertigation, permanent beds, contouring). Target by farm size.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding.*	Terrain	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
	Basin specific adoption data is currently not available.	• Extension informing strategic use of insecticides and fungicides. • Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	*Maintain this level as a minimum.*		
Grazing	**90% of grazing area in the Herbert basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** **Minimum 70 per cent late dry season groundcover on grazing lands.**	• Work with owners of properties that have been shown to have low levels of ground cover over the last ten years to reduce stocking rates which should in the longer term produce higher returns for those graziers. • Training course on soil health. • Training course on best practice road and fence construction.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain QDAFF	High
Dairy	**90% of dairy area in the Herbert basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** *Basin specific adoption data is currently not available.*	• Extension program to support shifts to B class practice. • Continued R&D into slow release fertilisers, innovative fertiliser reduction schemes.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain QDO QDAFF	Low
Mixed Cropping	**90% of mixed cropping area in the Herbert basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.** *Basin specific adoption data is currently not available.*	• Extension program to support shifts to B class practice, focusing on sediment management.	*Regional estimate will be provided based on level of investment in Reef Rescue 1 funding. Maintain this level as a minimum.*	Terrain	Low
Urban	**As a minimum, pollutant loads from urban areas do not increase beyond the 08-09 baseline.**	• Complete quantitative assessment of urban management practices and potential future coastal and industrial development. This will include calibration of MUSIC (stormwater model used by industry) for the Wet Tropics. • Identify management actions (current best practice or aspirational practice) required to (at	Total allocation across the region: $100,000 per annum. Note. The bulk of these costs are borne by urban development in terms of	Terrain and Hinchinbrook Shire Development industry FNQROC	Low

Program	Deliverable / Management Outcome Target	Management Actions / BMPs (relative priority shown in brackets)	Cost ($/year[a] or total[b])	Lead Agency and partners	Relative Priority within the Basin
		a minimum) maintain loads from urban areas at 08-09 baseline. • Appropriate resource allocation for the administration and overseeing that Erosion and Sediment Control Plans are developed and implemented. Focus on new developments due to large costs associated with retrofitting. • Capacity building to ensure industry and local government are able to manage stormwater quality. • Investigate use of stormwater water quality offsets to manage residual sediment loads after regulated performance standards have been met. • Ensure pre-development design (WSUD), incorporates water quality improvement measures for post-development outcomes.	compliance with regulation and standards. Therefore, WQIP funding is focussed on ensuring existing actions are effective and efficient.		
Other land uses	**Other horticulture: 90% of area in the Herbert basin is managed using best management practice systems (soil, nutrient and pesticides) by 2018. These levels should then be maintained beyond 2018 as a minimum.**	Current knowledge gap.	*Allocation to be determined from the proposed regional estimate of $1.25M/year for all agricultural industries except sugar cane.*	GrowCom, Terrain	Low
Protecting and maintaining values of catchment waterways, freshwater health and restoring ecological function of coastal ecosystems ***Management objective: Protect, Restore, Maintain and Adapt (Adapt largely in coastal floodplain area)***					
Riparian Vegetation	**The extent of riparian vegetation is increased by 2018.**	• Maintain restoration programs with active partnerships with Hinchinbrook Shire, catchment communities and Terrain.	To be determined through planning for regional system repair strategy.	Hinchinbrook Shire, Terrain, Catchment community	Moderate in Upper Herbert; Low in Lower Herbert
Wetlands	**There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.**	• Priority planning and implementation for replacement/modification of 10 priority fish barrier(culverts, causeways and tidal gates)	To be determined through planning for regional system repair strategy.	Hinchinbrook Shire, Individual landholders	Moderate

8.3 Enabling actions

A number of tasks and roles are required to support delivery and implementation of the WQIP. While it is proposed that the implementation of this whole WQIP would be led by Terrain NRM, the success of the plan will heavily rely on the maintenance, and in some cases establishment, of collaborative partnerships in the region. The main enabling actions, estimated annual costs, lead agency and partners are identified in Table 8.15. Some of these activities are already partially funded within Terrain through various initiatives, but the total estimate of approximately $1.8 million per year provides a holistic estimate.

Table 8.16. Enabling actions to support Wet Tropics WQIP implementation. Note that these figures do not factor in the Systems Repair component which requires further scoping in 2015-2016.

Enabling Actions	Description	Estimated cost per year (note does not include likely in-kind contributions)	Lead Agency and partners
Leadership	• Overall responsibility for oversight of WQIP implementation including overall project coordination. • Undertake mid-term review of the WQIP • Undertake final review of the WQIP	0.4 FTE plus operating $75,000	Terrain
Governance	• In partnership with the Australian government, Queensland Government and industry, ensure implementation of the priorities and strategic engagement with the local community is well coordinated between partners	4 x 0.5 day meetings per annum $2,000	Terrain to coordinate – use the Board?
Project management and delivery and monitoring	Total of 3 full-time staff. • Project Manager 1FTE to supervise overall project management in addition to incentive or extension delivery in collaboration with the Reef Programme. • Community Partnerships staff: 0.2 FTE per basin = ~2FTE across region.	3 FTE plus operating $350,000	Terrain and delivery partners
Communication and Engagement	1 full-time staff to lead communication and engagement activities. • Develop a Communication and Engagement Strategy for the implementation of the Wet Tropics WQIP and annual work plans. • Communication activities including catchment health report card every two years including summary of citizen science and continuous monitoring water quality data, research results and works completed. • Encourage community participation in activities e.g. citizen science programs, seminars to educate the community. • Hold stakeholder tours to highlight work sites, project outcomes and best management practices. • Undertake field days of demonstration sites aimed at encouraging BMP use on lifestyle properties.	1 FTE plus operating $160,000	Terrain and delivery partners

Enabling Actions	Description	Estimated cost per year (note does not include likely in-kind contributions)	Lead Agency and partners
Compliance and Auditing – stewardship payments	1 full-time position to oversee compliance in both the cane and banana industries. • Farm visits and assessment of performance against management agreements for BMP implementation and stewardship payments • It is important to have a person that is independent from the extension and incentive programs perform a proportion of landholder stewardship compliance assessments each year.	1 FTE plus operating $120,000	*Dependant on delivery mechanism
Urban investigations and planning	• Improved understanding of the nature, extent and location of future urban development and the capacity of runoff implications to be managed by development guidelines and local government processes.	0.4 FTE plus operating $100,000	Terrain in collaboration with FNQROC
Monitoring and evaluation	• Implementation of the monitoring and evaluation program outlined in Table 10.1 including combined reporting.	$500,000	Terrain, Queensland government, CSIRO and/or universities
Priority Research Themes to Fill Knowledge Gaps (short term)	• Identification of small scale pollutant hotspots that can be feasibly managed and improvement of relative risk assessment techniques	$60,000	Terrain, Queensland government, CSIRO and/or universities
	• Quantifying the environmental benefits and costs of ecological restoration projects and techniques for evaluating impacts	$200,000	
	• Evaluating the effectiveness of alternative management scenarios	$60,000	
	• Improved understanding of heterogeneity of factors that influence farm scale viability, including the economics of adoption for improved practices, across major agricultural sectors, including sugar cane, grazing, horticulture and row crops.	$100,000	
R&D Sub total: $580,000	• Regionally specific climate change scenarios	$60,000	
Synthesis of supporting knowledge	• Overarching synthesis of the key messages and outcomes arising from the combined research and monitoring outputs.	$100,000	Technical group
Total		$1,887,000 per year	

8.4 Budget Estimate

It is not possible at this time to provide a complete budget summary for the implementation of the WQIP, as a number of aspects still require further investigation (as identified in the Basin Implementation Plans). However, Table 8.16 provides an indicative but preliminary summary based on current information, indicating that an investment of at least $6 million per year would be required to fully implement the actions identified within the Wet Tropics WQIP. However, this amount only factors in planning actions for system repair and no on-ground works which would need to be addressed beyond the first 12 to 18 months. It also assumes that incentives would not be required to shift to agricultural practices which are demonstrated to be profitable, which may be unrealistic, at least in the first 2 to 3 years. This activity includes enabling actions such as project management, communications, monitoring and evaluation, a number of high priority research projects, actions to directly reduce pollutant loads and a strategy for commencing a system repair program for the Wet Tropics. Some of these items could be cost effectively undertaken as collaborative projects across the GBR with benefits to multiple policy platforms including Reef Plan and the Reef 2050 Long Term Sustainability Plan.

Table 8.17. Summary of preliminary cost estimates to implement the Wet Tropics WQIP over the first 5 years.

Item	Cost estimate per annum	Total Estimate over first 5 years
Leadership, governance, project management	$427,000	$2,135,000
Communication and Engagement	$160,000	$800,000
Compliance and Auditing – stewardship payments	$120,000	$600,000
Urban investigations and planning	$100,000	$500,000
Shifting to All B practices in sugar cane	$2,600,000	*$13,000,000
Shifting to All B practices in other agricultural industries	$1,250,000	**$6,250,000
System Repair actions	***$200,000	***$1,000,000 TBD
Monitoring and Evaluation	$500,000	$2,500,000
Priority research themes to fill knowledge gaps (preliminary assessment): • Identification of small scale pollutant hotspots that can be feasibly managed • Quantifying the environmental benefits and costs of ecological restoration projects • Evaluating the effectiveness of alternative management scenarios • Understanding the socio economic characteristics of practice change in agricultural industries • Regionally specific climate change scenarios	$580,000	$2,900,000
Synthesis of supporting knowledge	$100,000	$500,000
Estimated sub total	**$6,037,000**	$30,185,000
Contingency: Supports emerging priorities or measurement of episodic events	$150,000	$750,000
Total	**$6,187,000**	**$30,935,000**

*Sourced from the INFFER analysis,.

**Estimated from investment through the Wet Tropics Reef Rescue Water Quality Grants 2008 to 2013 in other agricultural industries (bananas, dairy, forestry, dry grazing, wet grazing, multi-crops, pawpaw and tree crops).

***Estimate to support planning and development of regional system repair strategy only. Does not include cost of any on-ground works.

9. Reasonable Assurance Statement

The science and economic analysis that underpins this WQIP has been undertaken to the best of our ability in the time available. We have used available published and unpublished information including technical expertise and local knowledge. We have engaged with many key scientists and economists involved in the collective Great Barrier Reef efforts in Queensland government agencies, CSIRO and universities. A collaborative and participatory approach has been used and we have invited comment and review of the key component pieces of work.

Despite a large research effort being undertaken on the GBR, significant knowledge gaps and uncertainties remain. We have endeavoured to be transparent about assumptions made. As knowledge improves, some aspects of the WQIP will change and be updated as part of adaptive management. Adaptive management is a systematic process to improve management effectiveness by adopting an explicit approach to learning and review (Eberhard et al., 2008). In the context of a WQIP, reasonable assurance statements assess the uncertainty associated with the knowledge base around developing targets, and the capacity to deliver actions to achieve targets.

A qualitative estimate of the uncertainties associated with the major pieces of work that underpin the WQIP are outlined below.

Values

Coral reefs – low/moderate uncertainty. The extent of coral reefs are well mapped and current status across the region is relatively well documented.

Seagrass areas –moderate/high uncertainty. The extent and status of seagrass beds in the region are not well mapped with limited locations where regular monitoring is undertaken.

Threats to values

Threats to values of the Reef – medium uncertainty. Threats to the Great Barrier Reef have been well articulated through the Scientific Consensus Statement 2013. More recently however the Statement of Outstanding Universal Value of the GBR and the analysis of condition and trend of elements that make up these values have been reviewed through the GBR Outlook Report 2014. This analysis may need to be updated in the context of the information collated in this WQIP. It is still clear though that the main threats to the GBR are land based impacts on water quality, port dredging and climate change. There is however significant uncertainty associated with the future impacts of climate change, particularly in relation to possible synergistic effects with other threats (Brodie et al., 2013a).

Risk assessment of degraded water quality to ecosystem values

Risk assessment – Low-medium uncertainty. Waterhouse et al. (2014) have conducted risk assessment work. While they comment that the confidence in the results is low to moderate due to limited validation of the remote sensing data in some locations, simple interpolation of the loading data, and limited availability of pesticide concentration data in rivers and the marine environment during flood events to determine pesticide concentration mapping, they conclude that patterns align with what might be expected intuitively given the influence of the adjacent land uses and river discharge characteristics.

Targets

Water quality load reduction targets – Medium. Reef Plan Targets have been available since 2009 and Ecologically Relevant targets have been much more recently developed (Brodie et al., 2014). Overall uncertainty of targets is assessed as Medium based on the fact that considerable knowledge gaps remain regarding the link between pollutant and effect on ecosystem components, and the fact that load reductions can only be modelled on annual time scales, whereas ecosystem response will be much finer and more subtle.

Economic analysis

Economic analysis of the sugar cane industry has been conducted in the Wet Tropics region (van Grieken et al., 2010, in press; Poggio et al., 2014). The WQIP built on and augmented previous economic analysis. A data compilation is available in a spreadsheet prepared by DAFF (Marcus Smith and others), and described in Park and Roberts (2014a). Major assumptions for the assessments are associated with heterogeneity, and cost estimates which are outlined in Section 4.2.

- Previous research evaluations of previous programs, and data provided by DAFF provide a reasonable basis for economic analysis (particularly costs).

- Sensitivity analysis has incorporated the known heterogeneity of inputs and this has produced a broad range from INFER analysis. This approach is deliberately conservative and is designed to paint a realistic understanding the economics underpinning this WQIP.
- Data and information inferred from other GBR regions is a reasonable proxy for the specific circumstances of the Wet Tropics.
- Design and evaluation of on-ground stewardship arrangements should result in greater levels of economic certainty over the short to medium term, as those arrangements will enable a more realistic range of estimates to be established based on on-ground experience.

Farm heterogeneity - Low-Medium uncertainty. Some heterogeneity has been captured in size and costs. However, heterogeneity relating to social factors (e.g. landholders' willingness to participate in programs and the impact on costs) has not been incorporated.

Profitability and costs - Low-Medium uncertainty. We used best available local expertise and built on available work conducted in other regions. However, experience from previous grants, stewardship payments and use of more sophisticated market-like approaches for programmes over the GBR suggest that significant variability in on-ground costs will still exist depending on a number of factors. These include the economic circumstances of participants, their perceptions of risk to practice change (technical and economic risk), landholder capacity, and other social drivers and impediments to change.

Pollutant load estimates

Land use/ constituent and process representation in Source Catchments – Moderate uncertainty. If the land use/ constituent processes are not adequately represented then this reduces confidence in results.

Different paddock scale models used - High. 'Apples' (eg APSIM) and 'oranges' (eg Howleaky, GRASP) are being compared rather than apples with apples. A further issues is that paddock scale models have not represented the full suite of possible landscape/climate/management scenarios.

Linkage between paddock and catchment modelling - Low uncertainty. Particularly when compared with some of the other issues raised. Modellers have spent a lot of time on this and developed purpose built tools.

Approaches to identification of practice effectiveness estimates from A, B, C, D practice suites for cane and grazing - High. There is limited data to test management practice effectiveness of individual practices. The definition of ABCD frameworks also varies between programs which has the potential to influence the results.

INFFER analysis - inputs

Effectiveness of practices themselves –Moderate uncertainty. There is limited field data on practice effectiveness. This uncertainty will reduce over time as on-ground programmes are rolled out and M&E is conducted.

Relative contributions between different practices (Risk framework) – Moderate uncertainty. There is extremely limited data on which to base estimates on.

Land use discrepancies – Low uncertainty. We adjusted cane land use area from Source modelling to better represent industry knowledge. Regardless this uncertainty is low compared with some of the other issues.

Lack of information on some land uses – Low uncertainty. The important land uses of sugar cane and grazing are covered.

Farm heterogeneity - Low-Medium uncertainty. Covered in economics section above.

Profitability and costs - Low-Medium uncertainty. Covered in economics section above.

INFFER analysis - results

INFFER – Low-Medium uncertainty. The INFFER analysis was used to assess the cost-effectiveness of actions to achieve targets. INFFER is based on theoretically sound Benefit:Cost analysis principles (Pannell et al., 2012). Despite the uncertainties of the inputs, there is confidence that the overall conclusions and implications of the results are sound. A sensitivity analysis has been conducted to explore the implications of uncertainty associated with variation in estimates of key parameter values. We believe that the level of uncertainty is reasonable for the purposes of the WQIP development. This is particularly the case as an underlying principle of our on-ground programmes will be to select projects that specifically incorporate cost-effectiveness considerations. This will capture the heterogeneity of actual on-ground projects and inform future applications of INFFER.

10. Monitoring, evaluation and reporting

10.1 Water quality monitoring and modelling strategy

Changes in water quality as a result of catchment management actions are only likely to be measurable at the smaller sub-catchment/land use scale in the shorter term. Determining a change/trend in end of river catchment loads due to management within the catchment through the general "catchment noise" is not feasible, due to factors such as long time lags in the system, large inter and intra annual variability, rainfall intensity and distribution (Stow et al., 2001; Osidele et al., 2003 in Bainbridge et al., 2008). As a result, a coupled monitoring and modelling approach is required. The extent of system "noise" will also vary depending on what water quality parameter is the focus, eg. Sediment lag times will be significantly longer than reductions in dissolved inorganic nitrogen through reductions in fertiliser application. Pesticide concentrations in waterways as a result of management actions may be reduced within 1-2 years.

For this reason the most effective form of monitoring to determine improvements in water quality at the end of catchment will be long term and strategically focused. Short-term improvements may be detected through a well-planned program based around 'isolated' reaches and water bodies associated with small sub catchments and relatively uniform land uses. Without this level of specificity there are too many variables and too much background 'interference' to derive any meaningful cause and effect information from water quality monitoring.

In 2008, the Reef Water Quality Partnership established a scientifically reviewed framework relevant for monitoring and evaluation of WQIPs in the GBR catchments and was used to guide the design of the Reef Plan Paddock to Reef Program. This framework identifies the need for information in four key areas:

1. **Baseline assessment** to: understand the biophysical, social and economic values associated with the GBR; the drivers of management practices that create risks to GBR resource condition and trend (RCT); and to understand the broad benefits and costs of actions to enhance RCT.
2. **Policy design** (including modification to existing policy), to ensure effective and efficient policies are developed that account for impediments to changing practices.
3. **Policy implementation** to achieve desired changes. It is assumed that the actions targeted under the policy implementation phase are developed based on science and will lead to changes in the resource condition trend. This is the area where the linkages between biophysical, social and economic sciences are vital to result in on-ground actions.
4. **Monitoring and evaluation** of biophysical, social and economic drivers and values to feedback into a comparison of the baseline assessment to measure change, and a feedback to inform policy design (adaptive management).

Many elements of the monitoring effort described in this strategy are already in place, although there are gaps related to social and economic monitoring in particular. The strategy aims to augment them, as needed, to allow a thorough assessment of the health of the resources that are important to the Wet Tropics community, and other influencing factors. The development of the WQIP has also identified key knowledge gaps to be addressed by further research and investigation work. As these gaps are addressed, improved knowledge and understanding will need to be integrated into monitoring and evaluation activities as appropriate.

The development of this monitoring strategy is based on the *Australian Guidelines for Water Quality Monitoring and Reporting (2000)* through the National Water Quality Management Strategy (ANZECC and ARMCANZ, 2000). These guidelines provide a framework for developing a water quality monitoring program and emphasise the need for a formal design process that includes:

1. Definition of the issue(s);
2. Compilation of available information;
3. Development of a conceptual model(s) for the system and problem of interest; and
4. Setting of clear, measurable objectives.

The Queensland Water Quality Guidelines[24] and the Queensland Water Quality Monitoring and Sampling Manual[25] also outline relevant procedures for monitoring.

Relevant evaluation questions include:

- What is the desired outcome of management for freshwater, coastal and marine ecosystems in the Wet Tropics NRM region?
- What are the ecological processes that determine the trajectories of freshwater, coastal and marine ecosystem recovery in the Wet Tropics NRM region?
- What are appropriate indicators of freshwater, coastal and marine ecosystem condition in the Wet Tropics NRM region?
- Do concentrations of pollutants and contaminants in Wet Tropics waterways exceed Queensland water quality guidelines?

The general objectives of the Wet Tropics WQIP monitoring and modelling program are:

- Understanding of the freshwater and coastal ecosystem health – measurement of pollutants/trends in water quality and ecosystem health/ responses.
- Understanding of the connectivity between freshwater, coastal and marine ecosystems, and associated functional connections and effectiveness.
- Identification and quantification of sources of pollutants to the GBR.
- Assessment of trends in delivery of pollutants (loads) to the GBR.
- Measurement of progress of implementation of pollutant-reducing initiatives on the GBR Catchment.
- Identification of the 'sink' areas of land-sourced pollutants in the GBR.
- Measurement of trends (spatial and temporal) in the concentrations of pollutants in compartments of the GBR– water column, sediments, biota.
- Assessment of the effects of pollutants on GBR ecosystems and trends in the status of GBR ecosystems related to terrestrial runoff.
- Assessment of the effects of terrestrial runoff on the GBR in relation to other stresses and impacts.

The proposed design of the integrated monitoring program for the Wet Tropics WQIP can be divided into five major categories:

1. Monitoring and modelling management actions and assessing effectiveness
2. Water quality monitoring and modelling
3. Freshwater and coastal ecosystem health monitoring
4. Receiving waters ecosystem health monitoring and modelling across the GBR (incorporating inshore, midshelf and offshore monitoring locations)
5. Monitoring of socio-economic indicators

The objectives, recommended indicators, opportunities for alignment and utilisation of existing programs, resources and gaps / future needs are outlined in Table 10.1. A map showing current monitoring sites across a range of program is shown in Figure 10.1.

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[24] https://www.ehp.qld.gov.au/water/guidelines/index.html
[25] https://www.ehp.qld.gov.au/water/monitoring/monitoring_and_sampling_manual.html

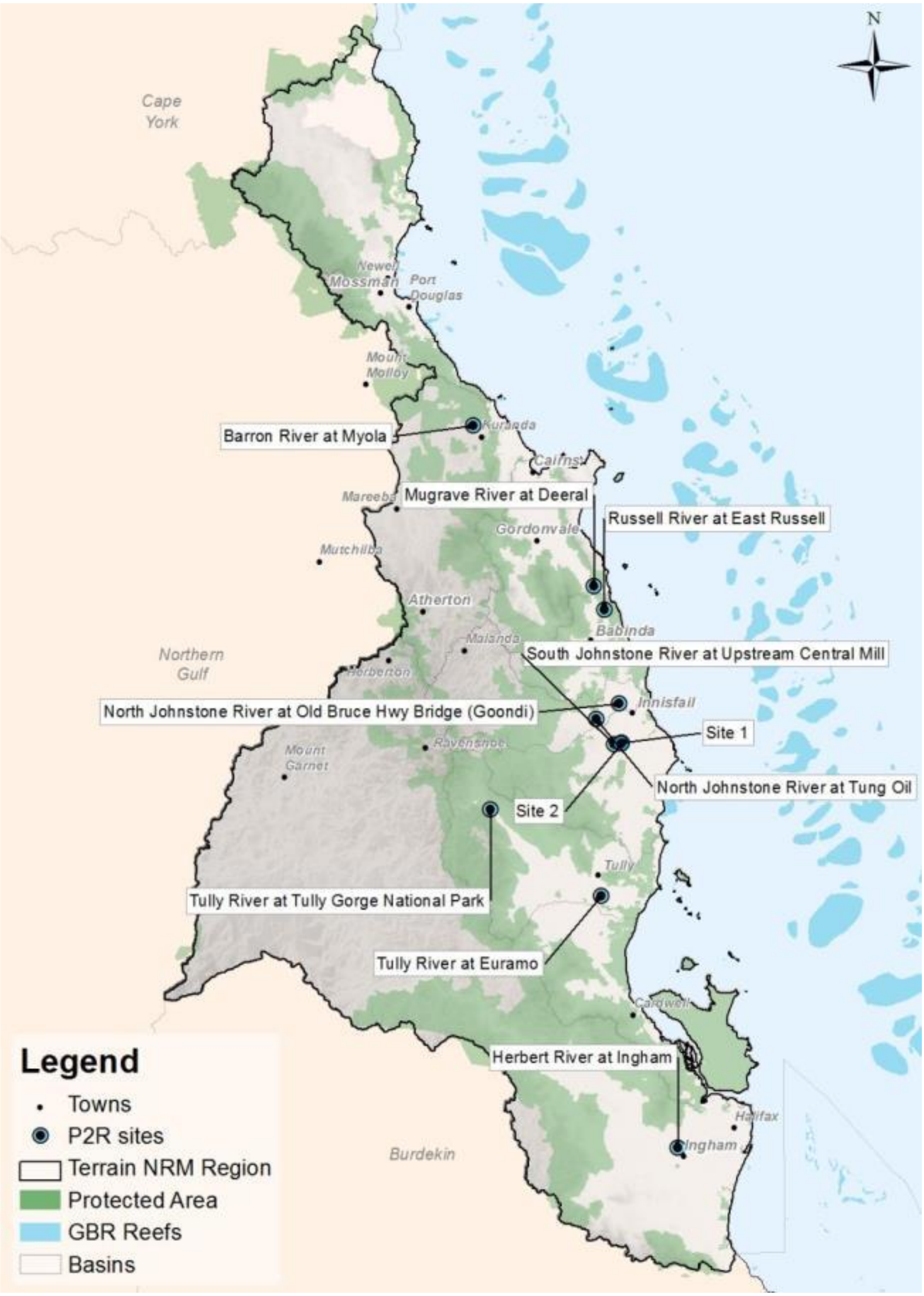

Figure 10.1. Location of key relevant monitoring sites to support implementation of the WQIP in the Wet Tropics region. Note that this will be updated as additional information is provided.

Table 10.1. Summary of monitoring and modelling objectives, indicators, existing programs and gaps to support the Wet Tropics WQIP.

Objective	Indicators	Existing Programs / Data Source
1.PRACTICE CHANGE:		
Monitoring and modelling management actions and assessing effectiveness		
Management action monitoring - agriculture	Adoption rates of management actions at a basin scale by industry in terms of level, percentage of participation and area of land.	P2R Management practice adoption monitoring program (Terrain, DAFF) Reef Rescue water quality grants database (Terrain)
	Stocking rates, Grass cover and biomass/pasture condition, Tree cover	P2R Land Condition monitoring (DSITIA)
	Riparian vegetation and wetland condition	P2R Land condition monitoring (DSITIA) P2R Wetland condition and extent monitoring program (DEHP, DSITIA)
	Engagement in water quality grants programs	Reef Programme water quality grants database (Terrain, industry)
	Participation in training and extension programs	Reef Programme water quality grants database (Terrain, industry)
Monitoring management practice surrogates	Fertiliser and pesticide use	Reef Programme (Terrain, industry)
	Spatial analysis of land use change	SLATS (DNRM)
Testing effectiveness of management practices	Field studies to quantify the water quality outcomes of particular management practices under a range of scenarios	Various R&D projects P2R case studies
Monitoring landscape context (eg. climate)	Recording significant climatic event eg. drought and flood	P2R Report Card context (DPC) Bureau of Meteorology data
Monitoring socio-economic context (eg. profitability)		Van Grieken et al (2010, 2014); Poggio et al (2014)
Management action monitoring - urban	Actions to be identified in consultation with local government	
Testing effectiveness of management actions	Assess benefits and costs of measures to reduce urban water quality impacts, including water sensitive urban design and retrofitting options.	
2. EFFECTIVENESS OF WORKS		
Water quality monitoring and modelling		
Freshwater water quality	Instream water quality monitoring.	Various projects by researchers as project funds are available. Condition assessments; Kroon et al. (2014), Godfrey and Pearson (2014) Tully Community WQ Pilot Project (Brodie and Tsatsaros,2012).
	Freshwater condition assessment.	
	Riparian condition assessment	

Objective	Indicators	Existing Programs / Data Source
Paddock Scale Monitoring/Research	Property scale water quality monitoring to measure the impact of particular management practices. Input into catchment scale modelling that is specific to land use/land types in the Regions.	P2R Paddock scale monitoring sites (2 cane, 2 banana) (QDAFF, industry, Terrain); Armour et al., (2014)
Sub-catchment	Sub catchment scale water quality monitoring to measure the longer term changes in water quality as a result of changes in land management practices and the impact of varying land uses. Input into catchment scale modelling that is specific to land use/land types in the region.	P2R GBR End of Catchment Loads program (DSITIA, Terrain); Turner et al., (2013). Herbert Water Quality Monitoring Project
Whole of catchment	Monitoring of water quality at end of catchment sites. Modelling to estimate end of catchment pollutant loads to enable load calculations to assess progress against basin end of catchment targets	P2R GBR End of Catchment Loads Monitoring program (DSITIA, Terrain); Ryan et al. (2014) P2R Source Catchments modelling program (DNRM); Hateley et al. (2014)
Estuarine and marine	Water quality monitoring in inshore waters (i.e. within 20 km of the coast) of the GBR to assess long-term change in the concentrations of key biophysical water quality indicators.	P2R Marine Monitoring Program (AIMS, TropWATER CSIRO); Schaffelke et al. (2014), Devlin et al., (2014), Johnson (2014)
River plumes	Water quality monitoring in river plumes to determine the composition of the material being transported in flood events to the inshore GBR, pollutant processing and comparison with GBR WQ Guidelines.	P2R Marine Monitoring Program (TropWATER); Devlin et al. (2014)
3. ENVIRONMENTAL OUTCOMES		
Freshwater ecosystem health monitoring and assessment		
Status and trends of the health of freshwater and coastal wetlands	Modelling protocol for productivity improvements that accompany change of estuarine and wetland (freshwater and coastal) ecosystem conditions and connectivity. Include modelled metrics for the high profile and high value species e.g. Mangrove Jack. Selected species are in essence surrogates for overall freshwater and marine biomass improvement.	No regional program exists.
	Wetland habitat. A modelling protocol for habitat improvements that accompany change of freshwater, estuarine and wetland conditions and connectivity. Include modelled metrics for plant assemblages TBD.	Queensland Wetland Program (DEHP & DSITIA)

Objective	Indicators	Existing Programs / Data Source
Receiving Waters Ecosystem Health Monitoring and Modelling	***Link with Reef 2050 Plan, for example:***	
Status and trends of the extent and health of mangrove communities	Inshore mangrove monitoring – mapping and assessment.	Queensland Wetland Program (DEHP and DSITIA) Mangrove Watch (TropWATER –Norm Duke)
Status and trends of the extent and health of seagrass communities	Inshore seagrass monitoring – mapping and habitat assessment, plant reproductive and tissue nutrient status within seagrass beds.	P2R Marine Monitoring Program (GBRMPA, DAFF); McKenzie et al. (2014a), McKenzie et al., (2014b) Ports North Trinity Inlet seagrass monitoring (TropWATER)
Status and trends of the health of coral reef communities	Inshore coral reef monitoring – cover and diversity, demography and recruitment.	P2R Marine Monitoring Program (AIMS and others); Thompson et al. (2014)
4. ENABLING ACTIONS / STAKEHOLDER ENGAGEMENT		
Monitoring of socio economic indicators	***Link with Reef 2050 Plan, for example:***	
	Population and population projection	ABS Census Data
	Economic and financial values of the GBR and catchments	Various projects by researchers as project funds are available, eg. Marsden Jacob Associates (2013), Turnour et al. (2013), Ramis et al. (2013), Prideaux and Thompson (2012),
	Community and visitor perceptions of the GBR	Coghlan and Prideaux (2012a,b), Prideaux and Sibtain (2012)
Knowledge and understanding of issues		
Stakeholder and community engagement	Surveys to benchmark and track knowledge and attitudinal change	

10.2 Adaptive management approach

An important part of the WQIP development and implementation process is the preparation of an adaptive management strategy. Adaptive management is particularly appropriate in dynamic and complex systems that result in high levels of uncertainty in delivery of actions and achievement of outcomes. These characteristics typify environmental management systems, in both biophysical and socio-economic aspects, and are strong features of the GBR system (Eberhard et al., 2009).

Furthermore, environmental and catchment management takes place in the context of human activity systems (social, economic and political) and a broad ecological context. It is important to acknowledge that the activities that are the focus of the WQIP occur within this broader socio-economic and ecological context. Other drivers, including possible land use intensification, demographic shifts, public land management and climate change will influence the elements described above and will need to be considered when addressing the key evaluation questions. In essence we are not managing the environment so much as guiding and influencing the people that impact the environment through their everyday behaviour. Adaptive management needs to incorporate and reflect the human activity systems operating in the area of influence and be designed to enable behavioural change in the relevant context.

Adaptive Management is an approach that involves learning from management actions, and using that learning to improve the next stage of management (Holling, 1978). It is "*learning to manage by managing to learn*" (Bormann et al., 1993). In simple terms adaptive management is the application of experiential learning to the management process. We start by managing the preparation of our strategic plan (a water quality improvement plan) and associated action plans, and then manage the plan implementation process i.e. project management. We implement actions devised as part of the WQIP and we review the outputs and outcomes of the actions. We learn from observation and evaluation of the results and we then incorporate the lessons into the action plans and continue to implement the actions.

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

10.3 Key assumptions and risks

Changes to industries: The WQIP has not taken into account potential land use change, or the influence of economic drivers on industries in the Wet Tropics region beyond the next 3-5 years. Governments have recently invested $17million in a Northern Australia Sustainable Futures program[26] including strategies around the future development of irrigated and mosaic agriculture, meat processing and infrastructure to further research and support northern development. Turnour et al. (2013) reports that the region's peak development organisations Regional Development Australia (Far North Queensland and Torres Strait) and Advance Cairns have identified agriculture as an important priority for future development (Advance Cairns 2011; Regional Development Australia, 2012).

An economic analysis of industry in the GBR catchments conducted by Marsden Jacobs and Associates (2013) identified several implications for the Wet Tropics WQIP:

- for sugar, policies and programs should focus on existing producers;
- for beef, options may be limited to address current loads (due to high groundcover), but some emphasis on managing the negative water quality risks of any future intensification in production may be warranted;
- for horticulture, significant growth in production areas may be less likely in the short to medium term due to market conditions. This will constrain growth in pollution loads unless current practices deteriorate;
- for mining, future risks are relatively uncertain, but there needs to be a continuation of managing future risks via existing regulatory processes with an emphasis on assessing the cumulative risks of future developments; and
- for urban, the implementation of WSUD will only partly mitigate the risks of future growth (primarily focussed in the Barron).

The areas identified for agricultural expansion as discussed in Section 8.1 have major potential implications for pollutant load runoff in the future. For example, expansion of cropping land uses to 7 to 10 times the current area in

[26] http://www.regional.gov.au/regional/ona/nasf.aspx

the region will have major implications for pollutant load runoff. The benefits of improved management practices would be far outweighed by any such expansions.

Continual improvement within the ABCD framework: It is recognised that the definitions (and hence, outcomes) of the industry ABCD classes will change as the water quality benefits and economic viability of new and innovative practices are proven and accepted over time. Therefore, the estimate of pollutant load reductions from practice shifts presented in the WQIP are essentially static, and do not take into account improvements in the magnitude of water quality benefits associated with each practice class over the 5 year period of the Implementation Plan (2018 to coincide with Reef Plan targets), towards the ecologically relevant targets (2035, i.e. 20 years from now) and the Reef 2050 Long Term Sustainability Plan (2050, i.e. 35 years from now).

10.4 Knowledge gaps and research needs

The development of the WQIP has revealed a series of key knowledge gaps to be addressed by further research and investigation work. As these gaps are addressed, improved knowledge and understanding will need to be integrated into monitoring and evaluation activities as appropriate.

The Plan identifies relationships between elevated pollutant loads on the condition and function of key ecosystem elements (e.g. seagrass, coral reefs, turtles and cetaceans, fish and bird populations), along with the supporting ecosystem processes. However, there are still substantial aspects of these relationships that require better understanding to guide management decisions. It is essential that the knowledge underpinning the anticipated cause-and effect relationships in the program logic is improved.

During the development of the Plan, key research activities have been identified to further improve understanding of the factors impacting on extent, condition and function of the asset area. These are presented in Tables 10.2, 10.3 and 10.4. However, as a supporting activity for implementation, this list needs to be focussed on what outcomes will be achieved and the priorities then assessed according to a set of criteria to which the projects can be ranked and a priority assigned. The criteria used in the Reef Plan review may be relevant and include:

1. **Outcomes and impact:** Will this option (research etc) improve short or long term outcomes for the Great Barrier Reef?
2. **Uncertainty:** Will this option reduce uncertainty (or increase reliability) in the program results and/or prediction of impacts of management change?
3. **Capacity:** Are there financial resources, available expertise and time to deliver this option?
4. **Comprehensive:** Will the option improve the comprehensiveness of the program (ie aid a system-wide management approach)?

Table 10.2. Ecosystem condition and trend Research Priorities.

No.	Major aim	Specific action	Review of previous studies
R1	Improve understanding of the response of key marine ecosystem components to poor water quality and the value of ecosystem services.	Refinement of the hydrodynamic modelling associated with the assessment of river discharges to the COTS outbreak initiation zone. Further development of the framework to assess ecosystem services in the region, and influence of poor water quality on these values.	Johnson, (2014) Thomas & Brodie, (2014)
R2	Seagrass condition and extent.	Further monitoring of the distribution and condition of seagrass habitats across the whole Wet Tropics marine region.	McKenzie et al. (2014)
R3	Coastal and estuarine ecosystem health assessments.	Extend habitat assessments beyond coral reefs and seagrass to include wetlands, mangroves, estuaries and non-reef ecosystems.	As above

No.	Major aim	Specific action	Review of previous studies
R4	Refine understanding of ecology and distribution of endemic freshwater fish species.	Conduct targeted surveys to determine the distribution of endemic aquatic species such as fishes and turtles, particularly within impacted catchments.	Pusey, B., Kennard, M., and Arthington, A., (2004) Januchowski-Hartley, S., Pearson, R., Puschendorf, R., Rayner, T., (2011)
R5	Evaluate condition of remnant palustrine wetlands; an ecosystem type that has been severely impacted in the Wet Tropics and plays an important ecosystem function.	Habitat assessments of remaining palustrine wetlands are required to determine their condition and ecosystem functionality.	Arthington, A., Godfrey, P., Pearson, R., Karim, F., Wallace, J., 2014
R6	Refine monitoring protocols to incorporate indicator groups such as fish or macro-invertebrates that may be sensitive to changes in water quality parameters.	Build on existing data relating to fish sensitivity to flow and promote further research into biological indicators to monitor biological and ecological responses to changes in water quality.	Januchowski-Hartley, S., Hermoso, V., Pressey, R., Linke, S., Kool, J., Pearson, R., Pusey, B., VanDerWal, J., 2011 Donaldson, J., Ebner B., & Fulton, C., 2013.
R7	Update inventory of aquatic invasive and translocated species.	Many of the extensive aquatic surveys in the Wet Tropics were undertaken more than 15 years ago, therefore extensive surveys are needed to update our knowledge of the distribution and composition of invasive species in the Wet Tropics.	Burrows, D., 2004
R8	Document fish, mollusc and crustacean fauna in short-steep-coastal streams; a unique aquatic habitat type in the context of Australia.	Conduct targeted surveys in short-steep-coastal streams to document fish, mollusc and crustacean communities which are likely to be similarly unique to the fish fauna.	No surveys of mollusc and crustacean fauna of short-steep-coastal streams have been published. Preliminary studies on fish fauna have been published: Ebner and Thuesen 2010; Ebner et al., 2011; Thuesen et al., 2011
R9	Improve quantitative understanding of ecosystem processes and water quality in relatively pristine 'reference catchments' (e.g. Bloomfield, Daintree) to compare with impacted systems.	Identify 'near pristine' catchments and quantitatively measure water quality parameters through the installation of logging stations and quantify ecosystem function using surrogates such as fish movement measured by telemetry arrays.	Pearson et al., 2010

Table 10.3. Ecological Linkages Research Priorities.

No.	Major aim	Specific action	Review of previous studies
R10	Improve understanding of risks to key ecosystem components from declining water quality.	Scoping of the availability of, and acquisition of, more consistent temporal and spatial data for all water quality variables (including those not included in the most recent assessment such as phosphorus and particulate nutrients) and their ecological impacts to enable improved classification in terms of ecological risk and application of a formal risk assessment framework	Risk Assessment - Waterhouse et al (2014)

No.	Major aim	Specific action	Review of previous studies
		(which includes assessments of likelihood and consequence). Further validation of remote sensing algorithms in coastal areas, particularly Chlorophyl values in highly turbid waters.	
R11	Improve understanding of the relative risk to different asset areas and values.	Examination of catchment sources of sediment resuspension events. Refine the ability to link marine relative risk to end of catchment loads including improved techniques for defining zones of influence for each river. Update the plume loading mapping to incorporate new hydrological modelling and load data.	Risk Assessment - Waterhouse et al (2014)
R12	Improve understanding of relationship between changes in water quality and ecosystem responses.	Review the appropriateness and adequacy of Reef Plan and Ecologically relevant Targets for maintaining and improving asset values.	Brodie et al. (2014)
R13	Assess current and predicted future impacts from climate change on key asset values.	Review current monitoring approach to ensure these impacts can be adequately considered in future implementation and evaluation activities. Improve understanding of the potential impacts of more frequent extreme events on asset values and recovery.	Review BoM data and CSIRO climate change predictions relative to Great Barrier Reef

Table 10.4. Catchment Management Research Priorities.

No.	Major aim	Specific action	Review of previous studies
R14	Improve understanding of catchment hydrological processes and relationship between land management practices and water quality.	Review and update modelling environment including: • Land use/constituent and process representation In Source Catchments • Integration of different paddock scale models • Understanding of the effectiveness of practices on pollutant processes	Review of assumptions in Source Catchments and P2R work for adequacy in assessing relationships between land management practices and water quality.
R15	Establish a bioeconomic model for land uses in the Wet Tropics region.	Review and update model to reflect improved understanding of: • Catchment modelling outputs and assumptions • Economics across key contributing land uses/industries • Extent of adoption of improved practices	No previous studies which explicitly link catchment targets to costs and load reduction have been conducted.
R16	Continue to examine and trial management practices that reduce nutrient and herbicide losses from sugar cane areas.	• Further innovative trials on N fertiliser application in all cropping lands to reduce DIN (and possibly PN) loss from paddocks while maintaining crop productivity (also applies for P). • Examine ways to promote denitrification in the landscape (i.e. building soil microbial communities, possibility of denitrification walls, wetlands) –	Refer to Sing and Barron (2014), Thorburn et al. (2013)

No.	Major aim	Specific action	Review of previous studies
		although note it is difficult during high flow events. • Trials on herbicide management (related to alternative herbicides and application procedures).	
R17	Improve understanding of the current practice in horticulture industries (vegetable and tree crops).	• Replicate approach used to assess sugar cane impacts for horticultural enterprises, including economic analysis of improved practice.	Few previous studies have been done. There will be a need for R&D if horticulture is to be better captured in terms of practice effectiveness.
R18	Improve understanding of the current and potential future impacts of urban development on pollutant loads and subsequent water quality impacts.	• Assess benefits and costs of measures to reduce urban water quality impacts, including water sensitive urban design and retrofitting options. • Investigate likely future extent of peri-urban development and implications for achievement of WQIP targets and objectives	Healthy Waterways/RUSMIG efforts may help and were not available at the time of the Wet Tropics WQIP. Urban efforts need to be able to be linked with agricultural sources through catchment modelling.

11. References

Advance Cairns, 2011. Tropical North Queensland Regional Economic Plan. The world's leading sustainable tropical region. Living, working and playing in a tropical paradise 2011-2031. http://www.advancecairns.com/files/media/original/027/675/a3f/advc12654-tnqrep-64ppa4e.pdf

ANRA, 2002. User guide: Australian Natural Resources Atlas URL http://nrmonline.nrm.gov.au /catalog/mql:2479 viewed 28 May 2011.

Arthington, A., Naiman, R.J., McClain, M.E. and Nilsson, 2010. Preserving the biodiversity and ecological services of rivers: New challenges and research opportunities', Freshwater Biology, Vol. 55, pp. 1–16.

ANZECC and ARMCANZ, 2000. Australian Guidelines for Water Quality Monitoring and Reporting. through the National Water Quality Management Strategy No.7. http://www.environment.gov.au/system/files/resources/0b71dfb9-8fea-44c7-a908-826118d403c8/files/nwqms-monitoring-reporting.pdf

Armour, J., Mortimore, C., Pathania, N., Wiltshire, N., Daniells, J., Masters, B. and Reghenzani, J. 2014. Minimising off - farm movement of nitrogen in the north Queensland banana industry. Report to the Reef Rescue Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (32 pp.).

Arthington, A.H., Godfrey, P.C., Pearson, R.G. Karim, F., and Wallace, J., 2014. Biodiversity values of remnant freshwater floodplain lagoons in agricultural catchments: evidence for fish of the Wet Tropics bioregion, northern Australia. Aquatic Conservation: Marine and Freshwater Ecosystems. doi: 10/1002/aqc.2489.

Bainbridge, Z.T., Brodie, J.E., Lewis, S.E., Waterhouse, J., Wilkinson, S.N., 2009. Utilising catchment modelling as a tool for monitoring Reef Rescue outcomes in the Great Barrier Reef catchment area. In '18thWorld IMACS Congress and MODSIM09 International Congress on Modelling and Simulation, July 2009'. (Eds R. S. Anderssen, R. D. Braddock and L. T. H. Newham.) pp. 3301–3307. (Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation: Canberra.)

Bainbridge, Z.T., Wolanski, E., Alvarez-Romero, J.G., Lewis, S.E., Brodie, J.E. 2012. Fine sediment and nutrient dynamics related to particle size and floc formation in a Burdekin River flood plume, Australia. Marine Pollution Bulletin 65, 236 – 248. doi: 10.1016/j.marpolbul.2012.01.043

Bainbridge, Z.T., Lewis, S.E., Smithers, S.G., Kuhnert, P.M., Henderson, B.L.,Brodie, J.E. 2014. Suspended sediment sources, transport and export from a large, seasonally-dry tropical catchment: Burdekin River catchment, Queensland, Australia. Water Resources Research 50 (11), 9067-9087.

Barron, F., Haynes, D. 2009. Barron Trinity Inlet Water Quality Improvement Plan. Terrain NRM. www.terrain.org.au/content/download/.../Barron_WQIP_Summary.pdf

Bartley, R., Bainbridge, Z.T., Lewis , S.E., Kroon, F.J., Wilkinson, S.N., Brodie J.E., Silburn, D.M. 2014. Relating sediment impacts on coral reefs to watershed sources, processes and management: A review. Science of the Total Environment 468-469, 1138-1153.

Beilharz, N., 2012. Australia's wild rice may help feed the world, ABC Radio, <http://www.abc.net.au/rural/news/ content/201207/s3557036.htm>.

Bennett, J., Sanders, N., Moulton, D., Phillips, N., Lukacs, G., Walker, K., Redfern, F. 2002. Guidelines for protecting Australian waterways, Land and Water Australia, Canberra.

Berkelmans, R., De'ath, G., Kininmonth, S., Skirving, W.J. 2004. A comparison of the 1998 and 2002 coral bleaching events on the Great Barrier Reef: spatial correlation, patterns, and predictions. Coral Reefs, 23, 74-83.

Bormann, B.T., Cunningham, P.G., Brookes, M.H., Manning, V.W., Collopy, M.W. 1993. Adaptive ecosystem management in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-341. 22pp..

Brinkman, R., Tonin, H., Furnas, M., Schaffelke, B., Fabricius, K. 2014. Targeted analysis of the linkages between river runoff and risks for crown-of-thorns starfish outbreaks in the Northern GBR Australian Institute of Marine Science. June 2014.

Brodie, J., Lewis, S., Bainbridge, Z., Mitchell, A., Waterhouse, J., Kroon, F., 2009. Pollutant discharge management target setting for rivers in the Great Barrier Reef Catchment Area. Marine and Freshwater Research 60, 1141–1149.

Brodie, J., Waterhouse, J., Schaffelke, B., Johnson, J.E., Kroon, F., Thorburn, P., Rolfe, J., Lewis, S., Warne, M.St.J., Fabricius, K., McKenzie, L., Devlin, M., 2013a. Reef Water Quality Scientific Consensus Statement 2013. Department of the Premier and Cabinet, Queensland Government, Brisbane.

Brodie, J., Waterhouse, J., Maynard, J., Bennett, J., Furnas, M., Devlin, M., Lewis, S., Collier, C., Schaffelke, B., Fabricius, K., Petus, C., da Silva, E., Zeh, D., Randall, L., Brando, V., McKenzie, L., O'Brien, D., Smith, R., Warne, M.St.J., Brinkman, R., Tonin, H., Bainbridge, Z., Bartley, R., Negri, A., Turner, R.D.R., Davis, A., Bentley, C., Mueller, J., Alvarez-Romero, J.G., Henry, N., Waters, D., Yorkston, H., Tracey, D. 2013a. Assessment of the relative risk of water quality to ecosystems of the Great Barrier Reef. A report to the Department of the Environment and Heritage Protection, Queensland Government, Brisbane. TropWATER Report 13/28, Townsville, Australia.

Brodie, J., Lewis, S., Wooldridge, S., Bainbridge, Z., Kroon, F. 2014. Ecologically relevant targets for pollutant discharge from the drainage basins of the Wet Tropics Region, Great Barrier Reef. TropWATER Report 14/33. June 2014 Draft for review.

Brooks, A., Spencer, J., Olley, J., Pietsch, T., Borombovits, D., Curwen, G., Shellberg, J., Howley, C., Gleeson, A., Simon, A., Bankhead, N., Klimetz, D., Eslami-Endargoli, L., Bourgeault, A. 2013, An empirically-based sediment budget for the Normanby Basin: sediment sources, sinks, and drivers on the Cape York Savannah, Australian Rivers Institute, Griffith University.

Bruinsma, C. 2001. Queensland Coastal Wetland Resources: Cape Tribulation to Bowling Green Bay. Information Series QI01064. Department of Primary Industries, Queensland, Brisbane.

Bruno, J.F., Selig, E.R., Casey, K.S., Page, C.A., Willis, B.L., Harvell, C.D.S., Melendy, A.M. 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. PLoS Biol 5 (e124), 1220-1227.

Bunn, S.E., Davies, P.M., Negus, P. and Treadwell, S. 1999. Aquatic food webs. In: Riparian Land Management Technical Guidelines, Volume One: Principles of Sound Management. S. Lovett and P. Price (eds). Land and Water Resources Research and Development Corporation, Canberra.

Burrows, D.W. 2004. Translocated Fishes in Streams of the Wet Tropics Region, North Queensland: Distribution and Potential Impact. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns (83pp).

Campbell, S.J., McKenzie, L.J., Kerville, S.P. 2006. Photosynthetic responses of seven tropical seagrasses to elevated seawater temperature. Journal of Experimental Marine Biology and Ecology, 330, 455–468.

Carilli, J.E., Prouty, N.G., Hughen, K.A., Norris, R.D. 2009. Century-scale records of land-based activities recorded in Mesoamerican coral cores. Marine Pollution Bulletin 58, 1835-1842.

Coghlan, A., Prideaux, B. 2012a. Patterns of reef tourism on the GBR, Tropical North Queensland and the Whitsundays. Report. Australian Government's Marine and Tropical Sciences Research Facility, James Cook University.

Coghlan, A., Prideaux, B. 2012b. Reef tourism drivers and trends: synthesis report: analysis of recreational and tourism use and impact on the Great Barrier Reef for managing sustainable tourism. Report. Australian Government's Marine and Tropical Sciences Research Facility.

Cogle, A.L, Keating, M.A., Langford, P.A., Gunton, J., Webb, I.S. 2011. runoff, soil loss, and nutrient transport from cropping systems on Red Ferrosols in tropical northern Australia. Soil Research (49) ,87-97. CSIRO Publishing.

Collier, C., Waycott, M., Ospina, A.G., 2012. Responses of four Indo-West Pacific seagrass species to shading. Marine Pollution Bulletin 65, 342-354.

Collier, C., 2013. Chapter 7: Review of the risks to seagrasses of the Great Barrier Reef caused by declining water quality. In: Assessment of the relative risk of water quality to ecosystems of the Great Barrier Reef: Supporting Studies. A report to the Department of the Environment and Heritage Protection, Queensland Government, Brisbane. TropWATER Report 13/30, Townsville, Australia.

Crook, D.A., Robertson, A.I. 1999. Relationships between riverine fish and woody debris: implications for lowland rivers. Marine and Freshwater Research 50, 941-953.

Davis, R. 2005. Douglas Shire Water Quality Improvement Plan. Douglas Shire Council.

De'ath, G., Fabricius, K.E., Sweatman, H., Puotinen, M., 2012. The 27–year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Sciences of the United States of America 109 (44), 17734-17735.

Department of Environment, 2015. Reef 2050 Long-Term Sustainability Plan. http://www.environment.gov.au/marine/great-barrier-reef/consultation/reef-2050-long-term-sustainability-plan

DEHP, 2014. Scheduled Environmental values (EVs) and water quality objectives (WQOs) for all Wet Tropics region surface and groundwaters under the Environmental Protection Policy (Water) 2009 http://www.ehp.qld.gov.au/water/policy/schedule1/wet_tropics_waters_scheduled_evs__wqos.html

DEH and DNR 1999. Testing the Waters: A Report on the Quality of Queensland Waters, Department of Environment and Heritage and Department of Natural Resources, Brisbane.

Devney, C.A., Short, M., Congdon, B.C. 2009. Cyclonic and anthropogenic influences on tern populations. Wildlife Research 36, 368–378. doi:10.1071/WR08142.

Devney, C.A., Caley, M.J., Congdon, B.C. 2010. Plasticity of noddy parents and offspring to sea-surface temperature anomalies. PLoS ONE, 5(7): e11891. doi:10.1371/journal.pone.0011891.

Donaldson, J.A.,Ebner, B.C..Fulton, C.J. 2013. Flow velocity underpins microhabitat selection by gobies of the Australian Wet Tropics. Freshwater Biology, 58, 1038–1051.

DSITIA, 2012. Land use summary 1999 - 2009: Great Barrier Reef catchments, Queensland Department of Science, Information Technology, Innovation and The Arts, Brisbane.

Dunn, H. 2000. Identifying and protecting rivers of high ecological value, occasional paper 01/00, Land and Water Resources Research and Development Corporation, Canberra.

Eberhard, R., Robinson, C., Waterhouse, J., Parslow, J., Hart, B., Grayson, R., Taylor, B. 2009. Adaptive management for water quality planning – from theory to practice. Marine and Freshwater Research 60, 1189-1195.

Ebner B.C., Thuesen P. 2011. Discovery of stream-cling goby assemblages (Stiphodon species) in the Australian Wet Tropics. Australian Journal of Zoology, 58, 331–340.

Ebner, B.C., Thuesen, P.A., Larson, H., Keith, P. 2011. A review of distribution, field observations and precautionary conservation requirements for sicydiine gobies in Australia. Cybium, 35, 397–414.

Erftemeijer, P.L.A., Lewis III, R.R. 2006. Environmental impacts of dredging on seagrasses: A review, Marine Pollution Bulletin, 52(12), 1553-1572.

Erftemeijer, P.L.A., Riegl, B., Hoeksema, B.W., Todd, P.A. 2012. Environmental impacts of dredging and other sediment disturbances on corals: A review. Marine Pollution Bulletin, 64, 1737–1765.

Fabricius, K., Okaji, K., De'ath, G., 2010. Three lines of evidence to link outbreaks of the crown-of thorns seastar Acanthaster planci to the release of larval food limitation. Coral Reefs 29, 593–605.

Fabricius, K. E., De'ath, G., Humphrey, C., Zagorskis, I., Schaffelke, B. 2013. Intra-annual variation in turbidity in response to terrestrial runoff on near-shore coral reefs of the Great Barrier Reef. Estuarine, Coastal and Shelf Science, 116, 57-65.

Fabricius, K.E., Logan, M., Weeks, S., Brodie, J. 2014. The effects of river run-off on water clarity across the central Great Barrier Reef, Marine

Flores, F., Hoogenboom, M.O., Smith, L.D., Cooper, T.F., Abrego, D., et al. 2012. Chronic exposure of corals to fine sediments: lethal and sub-lethal impacts. PloS One 7: e37795 doi:10.1371/journal.pone.0037795.

Furnas, M.J. 2003. Catchment and corals: terrestrial runoff to the Great Barrier Reef, Australian Institute of Marine Science, Townsville.

Furnas, M., Brinkman, R., Fabricius, K., Tonin, H., Schaffelke, B., 2013. Chapter 1: Linkages between river runoff, phytoplankton blooms and primary outbreaks of crown-of-thorns starfish in the Northern GBR. In: Assessment of the relative risk of water quality to ecosystems of the Great Barrier Reef: Supporting Studies. A report to the

Department of the Environment and Heritage Protection, Queensland Government, Brisbane. TropWATER Report 13/30, Townsville, Australia.

Great Barrier Reef Marine Park Authority, 2006. Environmental Status: Birds, In: State of the Reef Report. Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority, 2009. Water Quality Guidelines for the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority, Townsville, 99p.

Great Barrier Reef Marine Park Authority, 2013. A method for identifying and prioritising coastal ecosystem functional connections to the Great Barrier Reef World Heritage Area and Great Barrier Reef Marine Park. GBRMPA, Townsville.

Great Barrier Reef Marine Park Authority, 2014a. Great Barrier Reef Outlook Report 2014. GBRMPA, Townsville.

Great Barrier Reef Marine Park Authority, 2014b. Great Barrier Reef Strategic Assessment., GBRMPA, Townsville.

Grech, A., Bos, M., Brodie, J., Coles, R., Dale, A. et al. 2013. Guiding principles for the improved governance of port and shipping impacts in the Great Barrier Reef. Marine Pollution Bulletin, 75, 8-20.

Gillespie Economics and BDA Group, 2008. Economic Activity of Australia’s World Heritage Areas. Report to the Department of the Environment, Water, Heritage and the Arts, July 2008.

Godfrey, P.C., Pearson, R.G. 2012. Wet Tropics Waterways Condition Assessment: Mulgrave, Russell, Johnstone and Herbert Rivers. Report to Terrain Natural Resource Management and the Department of Environment and Heritage Protection. ACTFR Report No. 12/03, James Cook University.

Greenhalgh, S., Selman, M. 2012. Comparing water quality trading programs: What lessons are there to learn? Journal of Regional Analysis and Policy 42(2), 104-125.

Gunn, J. 2014. Urban Land Use in Great Barrier Reef Water Quality Improvement Plans: Background Report and Considered Guidance, Reef Urban Stormwater Management Improvement Group (RUSMIG), Water by Design and Creek to Coral, Townsville.

Haapkyla, J., Unsworth, K.F., Flavell, M., Bourne, D.G., Schaffelke, B., Willis, B.L. 2011. Seasonal Rainfall and Runoff Promote Coral Disease on an Inshore Reef. Plos One, 6(2): e16893.

Hateley, L.R., Ellis, R., Shaw, M., Waters, D., Carroll, C. 2014. Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Wet Tropics NRM region, Technical Report, Volume 3, Queensland Department of Natural Resources and Mines, Cairns, QLD (ISBN: 978-0-7345-0441-8).

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., Hatziolos, M.E. 2007. Coral reefs under rapid climate change and ocean acidification. Science, 318, 1737-1742.

Holling, C. S. (Ed.) 1978. ‘Adaptive Environmental Assessment and Management.’ (Wiley: London.)

Januchowski-Hartley S.R., Pearson R.G., Puschendorf R., Rayner T. 2011. Freshwaters and Fish diversity: Distribution, protection and disturbance in tropical Australia. PLOS One 6 (10): e25846. DOI:10.1371/journal.pone.025846

Januchowski-Hartley, S.R., Hermoso, V., Pressey, R.L., Linke, S., Kool, J., Pearson, R.G.,Pusey, B. 2011. Coarse-filter surrogates do not represent freshwater fish diversity at a regional scale. Biological Conservation 144: 2499-2511.

Johnson, J.E., Maynard, J.A., Devlin, M.J., Wilkinson, S., Anthony, K.R.N., Yorkston, H., Heron, S.F., Puotinen, M.L., van Hooidon, R. 2013. Chapter 2: Resilience of Great Barrier Reef marine ecosystems and drivers of change. In: Synthesis of evidence to support the Reef Water Quality Scientific Consensus Statement 2013. Department of the Premier and Cabinet, Queensland Government, Brisbane, 35pp.

Johnson, J. 2014. Status of coastal and marine assets in the Wet Tropics region. Prepared for Terrain NRM for the Wet Tropics Water Quality Improvement Plan by C2O Consulting, May 2014.

Kroon, F.J. 2008. Draft Tully Water Quality Improvement Plan. Report to Terrain Natural Resource Management. CSIRO Sustainable Ecosystems, Atherton, Qld.

Kroon, F., Joehnk, F., Williams, K.J., Dunlop, M. 2012. Queensland's biodiversity under climate change: freshwater ecosystems. CSIRO Climate Adaptation Flagship Canberra, Australia.

Kroon, F.J., Philip, S., Donaldson, J., Ebner, B. 2014. Assessment of freshwater ecosystem condition, status and trends in the Wet Tropics region. Supporting study to the Wet Tropics Water Quality Improvement Plan. CSIRO, Australia.

Kutser T., Metsamaa, L., Vahtmae, E., Aps R. 2007. Operative monitoring of the extent of dredging plumes in coastal ecosystems using MODIS satellite imagery, Journal of Coastal Research, SI50, 180-184.

Lawson, T., Kroon, F., Russell, J., Thuesen, P. 2010. Audit and prioritisation of physical barriers to fish passage in the Wet Tropics region. Milestone report, MTSRF project 2.6.2. CSIRO

Lewis, S.E., Smith, R., Brodie, J.E., Bainbridge, Z.T., Davis, A.M., Turner, R. 2011. Using monitoring data to model herbicides exported to the Great Barrier Reef, Australia. In Chan, F., Marinova, D. and Anderssen, R.S. (eds) MODSIM2011, 19th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2011, pp. 2051-2056. ISBN: 978-0-9872143-1-7. www.mssanz.org.au/modsim2011/E5/lewis.pdf

Lewis, S.E., Brodie, J.E., McCulloch, M.T., Mallela, J., Jupiter, S.D., Stuart Williams, H., Lough, J.M., Matson, E.G. 2012. An assessment of an environmental gradient using coral geochemical records, Whitsunday Islands, Great Barrier Reef, Australia. Marine Pollution Bulletin 65, 306-319.

Lewis, S., Brodie, J., Endo, G., Lough, J., Bainbridge, Z. 2014a. Synthesizing historical land use change, fertiliser and pesticide usage and pollutant load data in the regulated catchments to quantify baseline and changing pollutant loads exported to the Great Barrier Reef. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Technical Report 14/20, James Cook University, Townsville, 103 pp.

Lewis, S. E., Olley, J., Furuichi, T., Sharma, A., Burton, J. 2014b. Complex sediment deposition history on a wide continental shelf: Implications for the calculation of accumulation rates on the Great Barrier Reef. Earth and Planetary Science Letters 393, 146-158.

Little, I. 2014. Upper Herbert River Catchment Sediment Sources & Rehabilitation Opportunities April 2014. A report to Terrain NRM, April 2014.

Logan, M., Fabricius, K., Weeks, S., Canto, M., Noonan, S., Wolanski, E., Brodie, J., 2013. The relationship between Burdekin River discharges and photic depth in the central Great Barrier Reef. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns. 29 pp.

Logan, M., Fabricius, K., Weeks, S., Rodriguez, A., Lewis, S., Brodie, J. 2014. Tracking coastal turbidity over time and demonstrating the effects of river discharge events on regional turbidity in the GBR: Southern and Northern NRM Regions. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns.

Lynch, J.A., Rishel, G.B., Corbett, E.S. 1984. Thermal alteration of streams draining clearcut watersheds: quantification and biological implications. Hydrobiologia 111, 161-169.

Masters, B., Rohde, K., Gurner, N., Higham, W., Drewry, J., 2008. Sediment, nutrient and herbicide runoff from cane farming practices in the Mackay Whitsun-day region: a field-based rainfall simulation study of management practices. Queensland Department of Natural Resources and Water for the Mackay Whitsunday Natural Resource Management Group, Australia

McClurg, J.I., Powell, B., Morrison, D., Norman, P., Hampson, R.J. 2009. Acid Sulfate Soil Water Quality Improvement Plan, Far North Queensland. Department of Environment and Resource Management. NQAS 1, ISBN 978-1-7423-0013-9.

Macgregor, C., Cook, B., Farrell, C., Mazzella, L. 2011. Assessment framework for prioritising waterways for management in Western Australia, Centre of Excellence in Natural Resource Management, University of Western Australia, Albany.

McDonald, G., Weston, N. 2004. Sustaining the Wet Tropics: A Regional Plan for Natural Resource Management Volume 1: Background to the Plan, Rainforest Corporate Research Centre and Far North Queensland Natural Resource Management Ltd, Cairns.

McKenzie, L.J., Smith, N., Johns, L., Yoshida, R., Coles, R. 2014. Development of Wet Tropics WQIP elements – seagrass monitoring. A report to Terrain NRM, Innisfail. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Report 14/37. James Cook University, Cairns, Australia. 29pp.

Marsden Jacob Associates, 2013. Draft report on the economic and social impacts of protecting environmental values in Great Barrier Reef catchment waterways and the reef lagoon" Report prepared for Queensland Department of Environment and Heritage Protection.

Negus. P., Steward, A., Blessing, J. 2013. Queensland interim biological guidelines for Wet Tropics coastal streams: Aquatic macroinvertebrates, April 2013 – Draft for Comment. Brisbane: Department of Science, Information Technology, Innovation and the Arts, Queensland Government.

O'Brien D., Lewis S., Gallen, C., O'Brien, J., Thompson, K., Eaglesham, G., Mueller, J. 2014. Barron River pesticide monitoring and Cairns WWTP WQ assessment. Report No. 14/40, Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University, Cairns, 48 pp.

Osidele, O., Zeng, W., Beck, M. 2003. Coping with uncertainty: A case study in sediment transport and nutrient load analysis. J. Water Resources Planning and Management, 4: 345-355.

Osborne, L.L., Kovacic, D.A. 1993. Riparian vegetated buffer strips in water quality restoration and stream management. Freshwater Biology 29, 243-258.

Pannell, D. 2008. Public benefits, private benefits, and policy intervention for land-use change for environmental benefits. Land Economics, 84(2), 225–240.

Pannell, D., Roberts, A., Park, G., Alexander, J., Curatolo, A., Marsh, S. 2012. Integrated assessment of public investment in land-use change to protect environmental assets in Australia. Land Use Policy, 29(2), 377–387.

Park, G., Roberts, A. 2014a. Wet Tropics WQIP – INFFER Assessment . Final Report to Terrain NRM for the Wet Tropics Water Quality Improvement Plan, version 4 August 2014.

Park, G., Roberts, A. 2014b. Wet Tropics WQIP – INFFER Assessment: Basin prioritisation scenarios. Final Report to Terrain NRM for the Wet Tropics Water Quality Improvement Plan, version 19 August 2014.

Pearson, R.G., Crossland, M., Butler, B., Manwaring, S. 2003. Effects of cane-field drainage on the ecology of tropical waterways. 3 volumes, 39+76+81 pp. Report on SRDC projects JCU016 & JCU024 Australian Centre for Tropical Freshwater Research Report No. 3/04-1-3.

Pearson, R.G., Godfrey, P.C., Arthington, A.H., Wallace, J., Karim, F. and Ellison, M. 2013. Biophysical status of remnant freshwater floodplain lagoons in the Great Barrier Reef catchment: a challenge for assessment and monitoring. Marine and Freshwater Research 64, 208-222.

Petus, C., Collier, C., Devlin, M., Rasheed, M., McKenna, S. 2014. Using MODIS data for understanding changes in seagrass meadow health: a case study in the Great Barrier Reef (Australia). Marine Environmental Research 98, 68–85.

Prasertsak, P., Freney, J.R., Denmead, O.T., Saffigna, P.G., Prove, B.G., Reghenzani, J.R. 2012. Effect of fertiliser placement on nitrogen loss from sugarcane in tropical Queensland. Nutrient Cycling in Agroecosystems vol.62 issue march 2002.p 229-239.

Prideaux, B., Sibtain, J. 2012. Rainforest tourism final report: January 2007–December 2009 patterns of rainforest tourism in the Wet Tropics World Heritage Area, North Queensland. Report. Australian Government's Marine and Tropical Sciences Research Facility.

Pringle, C.M. 1996. Atyid shrimps (Decapoda: Atyidae) influence the spatial heterogeneity of algal communities over different scales in tropical montane streams, Puerto Rico. Freshwater Biology 35:125-140.

Peck, D.R., Smithers, B.V., Krockenberger, A.K., Congdon, B.C. 2004. Sea surface temperature constrains wedge-tailed shearwater foraging success within breeding seasons. Marine Ecology Progress Series, 281, 259–266.

Perez, M. and Romero, J. 1992. Photosynthetic response to light and temperature of the seagrass Cymodocea nodosa and the prediction of its seasonality. Aquatic Botany, 43, 51–62.

Poggio, M., Smith, M., van Grieken, M., Shaw, M., Biggs, J. 2014. The Economics of Pesticide Management Practices Leading to Water Quality Improvement on Sugarcane Farms. Department of Agriculture, Fisheries and Forestry (DAFF), Queensland.

Ports North, 2014. Ports North Annual Report 2013-14. http://www.portsnorth.com.au/pdfs/annual-reports/2013-2014AnnualReport.pdf

Prosser, I.P., Rutherfurd, I.D., Olley, J.M., Young, W.J., Wallbrink, PJ., Moran, C.J. 2001. Large-scale patterns of erosion and sediment transport in river networks, with examples from Australia. Marine and Freshwater Research 52, 81-99.

Prove, B.G., Moody, P.W., Reghenzani, J.R., 1997. Nutrient balances and transport from agricultural land and rainforest lands: a case study in the Johnstone River catchment. DAQ3S Final Report. Queensland Department of Natural Resources and BSES, Queensland.

Pusey, B.J.,Arthington, A.H. 2003. Importance of the riparian zone to the conservation and management of freshwater fish: a review. Marine and Freshwater Research 54, 1–16.

Pusey B.J., Kennard M.J., Arthington A.H. 2004. Freshwater Fishes of North-Eastern Australia, pp. 702. CSIRO Publishing, Melbourne, Vic.

Queensland Government, 2011, SILO Climate Data [Homepage of Queensland Government], [Online]. Available: www.longpaddock.qld.gov.au [2012, 02/22].

Queensland Wetlands Program, 2014. http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/nrm-terrain-nrm/

Queensland Department of Agriculture, Fisheries and Forestry (2014). Queensland Agricultural Land Audit. Queensland Government. http://www.daff.qld.gov.au/environment/ag-land-audit.

Ralph, P.J. 1998. Photosynthetic response of laboratory-cultured Halophila ovalis to thermal stress. Marine Ecology Progress Series, 171, 123–130.

Ramis, M., Prideaux, B. 2013. The importance of visitor perceptions in estimating how climate change will affect future tourist flows to the Great Barrier Reef. In: Reddy, Maharaj Vijay, and Wilkes, Keith, (eds.) Tourism, Climate Change and Sustainability. Taylor & Francis, Oxon, RN, pp. 173-188

Regional Development Australia, 2012. National Charter, Regional Development Australia, www.rda.gov.au.

Roberts, A., Craig, R. 2014. Regulatory reform requirements to address diffuse source water quality problems in Australia: learning from U.S experiences. Australasian Journal of Environmental Management, 21(1), 102–115.

Roth, C.H., Prosser, I.P., Post, D.A., Gross, J.E., Webb, M.J. 2003. Reducing sediment export from the Burdekin Catchment. Final Report to Meat and Livestock Australia, Project number NAP3.224, CSIRO, Canberra.

Rowlings, D., Koci, J., Nelson, P., Kowitz, R. 2014. Validating the cost/benefits of improved fertiliser practices and quantifying nutrient loads and pathways from irrigated dairy pastures in the Wet Tropics and the Burnett-Mary regions. Report to the Reef Rescue Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (131pp.).

Schaffelke, B., Anthony, K., Blake, J., Brodie, J., Collier, C., Devlin, M., Fabricius, K., Martin, K., McKenzie, L., Negri, A., Ronan, M., Thompson, A. and Warne, M. 2013. 2013 Scientific Consensus Statement. Chapter 1: Marine and coastal ecosystem impacts The State of Queensland. Published by the Reef Water Quality Protection Plan Secretariat, July 2013. http://www.reefplan.qld.gov.au/about/scientific-consensus-statement/ecosystem-impacts.aspx

Seddell, J.R., Reeves, G.H., Hauer, F.R., Stanford, J.A.,Hawkins, C.P. 1990. Role of refugia in recovery from disturbance: modern fragmented and disconnected river systems. Environmental Management 14, 711-724.

Selig, E.R., Harvell, C.D., Bruno, J.F., Willis, B.L., Page, C.A., Casey, K.S., Sweatman, H. 2006. Analysing the relationship between ocean temperature anomalies and coral disease outbreaks at broad spatial scales. Coral reefs and climate change: Science and management. Washington (DC): American Geophysical Union, 111-128.

Sing, N., Barron, F. 2014. Management practice synthesis for the Wet Tropics region. August 2014. A report prepared for the Wet Tropics Water Quality Improvement Plan. Terrain NRM, Innisfail.

Smith, R., Warne, M. St. J., Delaney, K., Turner, R., Seery, C., Pradella, N., Vardy, S., Rogers, B., Arango, C., Edge, K., Julli, M., in prep. Proposed guideline values for six priority pesticides of the Great Barrier Reef and its adjacent catchments.

Smithers, B.V., Peck, D.R., Krokenberger, A.K., Congdon, B.B. 2003. Elevated sea-surface temperature, reduced provisioning and reproductive failure of wedge-tailed shearwaters (Puffinus pacificus) in the southern Great Barrier Reef, Australia. Marine and Freshwater Research, 54, 973-977.

Spearman, J., Bray, R.N, Land, J., Burt, T.N., Mead, C.T., Scott, D. 2007. Plume dispersion modelling using dynamic representation of trailer dredger source terms. Proceedings in Marine Science, 8, 417–448.

Stow, C., Borsuk, M. and Stanley, D. 2001. Long-term changes in watershed nutrient inputs and riverine exports in the Neuse River, North Carolina. Water Research, 35: 1489-1499.

Sydes, T. in prep. Wet Tropics WQIP Systems Repair – Spatial Planning Framework. Far North Queensland Regional Organisation of Councils.

Terrain NRM 2008 Summary of the Tully Water Quality Improvement Plan: Summary.

Terrain NRM 2012. Consultation Report: Environmental Values for the Wet Tropics Basins. Further copies of the report may be obtained from www.terrain.org.au using the link http://www.terrain.org.au/programs/water/water-quality/617-healthy-water-management-plan.html

Thomas, C.R. and Brodie, J. 2014. Valuation of environmental benefits derived from the Burnett Mary Region, Great Barrier Reef. A report to Terrain NRM, Innisfail. TropWATER Report 14/30, James Cook University, Townsville, Australia, 36 pp.

Thompson, M., Prideaux, B. 2012. Interdependency of reef and rainforest tourism: a segmentation analysis of visitors to Tropical North Queensland. Report. Australian Government's Marine and Tropical Sciences Research Facility.

Thompson, A., Schaffelke, B., Logan, M., Costello, P., Davidson, J., Doyle, J., Furnas, M., Gunn, K., Liddy, M., Skuza, M., Uthicke, S., Wright, M., Zagorkskis, I. 2013. Reef Rescue Marine Monitoring Program. Final Report of AIMS Activities 2012 to 2013 – Inshore water quality and coral reef monitoring. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science, Townsville. 178pp.

Thompson, A., Costello, P., Davidson, J., Logan, M., Schaffelke, B., Uthicke, S., Takahashi, M. 2011. Reef Rescue Marine Monitoirng Program. Report of AIMS Activities – Inshore coral reef monitoring 2011. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science, Townsville. 128pp.

Thorburn, P.J., Wilkinson, S.N., Silburn, D.M. 2013. Water quality in agricultural lands draining to the Great Barrier Reef: A review of causes, management and priorities, Agriculture, Ecosystems and Environment 180, 4-20.

Thorburn, P., Rolfe, J., Wilkinson, S., Silburn, M., Blake, J., Gongora, M., Windle, J., VanderGragt, M., Wegschield, C., Ronan, M., Carroll, C., 2013. Chapter 5: The water quality and economic benefits of agricultural management practices. Reef Water Quality Scientific Consensus Statement 2013. Department of the Premier and Cabinet, Queensland Government, Brisbane.

Thuesen P.A., Ebner B.C., Larson H., Keith P., Silcock R.M., Prince J. et al. 2011. Amphidromy links a newly documented fish community of continental Australian streams, to Oceanic Islands of the West Pacific. PLoS ONE, 6, e26685.

Turner, R., Huggins, R., Wallace, R., Smith, R., Vardy, S., Warne, M.St.J., 2013. Loads of sediment, nutrients and pesticides discharged from high priority Queensland rivers in 2010-2011. Great Barrier Reef Catchment Loads Monitoring Program, Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Turnour, J., McShane, C., Thompson, M., Dale, A., Prideaux, B., Atkinson, M. 2013. Accounting for agriculture in place-based frameworks for regional development : Discussion paper. James Cook University, The Cairns Institute, Cairns 2013.

Van Grieken, M.E., Poggio, M.J., East, M., Page, J. and Star, M., 2010. Economic Analysis of Sugarcane Farming Systems for Water Quality Improvement in the Great Barrier Reef Catchments. Reef Rescue Integrated Paddock to Reef Monitoring, Modelling and Reporting Program. CSIRO: Water for a healthy Country National Research Flagship.

Van Grieken, M., Poggio, M., Smith, M., Taylor, B., Thorburn, P., Biggs, J., Whitten, S., Faure, C., and Boullier, A. 2014. Cost-effectiveness of management activities for water quality improvement in sugarcane farming. Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns.

van Hooidonk, R., Maynard, J. A., and Planes, S. 2013 Temporary refugia for coral reefs in a warming world. Nature Climate Change.

Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A. 2004. Resilience, Adaptability and Transformability in Social–ecological Systems. Ecology and Society 9(2). Online URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Ward, J.V., and J.A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11: 105-119.

Waterhouse, J., Brodie, J., Lewis, S., Mitchell, A., 2012. Quantifying the sources of pollutants in the Great Barrier Reef catchments and the relative risk to reef ecosystems. Marine Pollution Bulletin 65, 394-406.

Waterhouse, J., Brodie, J., Tracey, D., Lewis, S., Brinkman, R., Tonin, H., Furnas, M., Fabricius, K., Schaffelke, B., Wolff, N., Devlin, M., McKenzie, L. 2014. Assessment of the relative risk of water quality to ecosystems of the Wet Tropics Region, Great Barrier Reef. A report to Terrain NRM, Innisfail. TropWATER Report 14/27, Townsville, Australia.

Waycott, M., McKenzie, L., Mellors, J., Ellison, J., Sheaves, M., Collier, C., Schwarz, A.M., Webb, A., Johnson, J.E., Payri, C. 2011. Chapter 6: Vulnerability of mangrove, seagrass and intertidal sand and mud flat habitats in the tropical Pacific to climate change. In: Vulnerability of tropical Pacific fisheries and aquaculture to climate change, eds Bell J., Johnson J.E. and Hobday A.J. Secretariat of the Pacific Community, Noumea, New Caledonia.

Webster, A.J., Bartley, R., Armour, J.D., Brodie, J.E., Thorburn, P.J., 2012. Reducing dissolved inorganic nitrogen in surface runoff water from sugarcane production systems. Mar. Poll. Bull. 65, 128–135.

Wenger, A.S., Johansen, J.L., Jones, G.P. 2011. Suspended sediment impairs habitat choice and chemosensory discrimination in two coral reef fishes. Coral Reefs 30, 879-887

Wiedenmann, J., D'Angelo, C., Smith, E.G., Hunt, A.N., Legiret, F.E., Postle, A.D., Achterberg, E.P. 2013. Nutrient enrichment can increase the susceptibility of reef corals to bleaching. Nature Climate Change 3, 160-164.

Wooldridge, S.A., Brodie, J., Furnas, M., 2006. Exposure of inner-shelf reefs to nutrient enriched runoff entering the Great Barrier Reef Lagoon: post-European changes and the design of water quality targets. Marine Pollution Bulletin 52, 1467–1479.

Wooldridge, S., Brodie, J., Kroon, F.J. in review. Ecologically relevant targets for dissolved inorganic nitrogen (DIN) discharge from the drainage basins of the Wet Tropics Region, Great Barrier Reef. Marine Pollution Bulletin.

12. Appendices

Appendix 1: Additional legislative and policy context for developing the Wet Tropics WQIP

Appendix 2: Experts involved in the INFFER workshops and review of the WQIP

Appendix 3: Summary of pollutant loads for the Wet Tropics NRM region.

Appendix 4: Wet Tropics NRM Region ABCD Management Practice Framework

Appendix 5: Draft Water Quality Improvement Actions for Developing Urban Environments

Appendix 6: Wet Tropics sugar cane INFFER analysis: Basin specific comparisons

Appendix 1: Additional legislative and policy context for developing the Wet Tropics WQIP

WQIPs have had a focus on receiving waters, i.e. the Great Barrier Reef.

The principal legislation relating to protection and management of the GBR is the Commonwealth Great Barrier Reef Marine Park Act and its supporting Great Barrier Reef Marine Park Regulations 1983(the Regulations). The main object of this Act is to provide for the long term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region.

In addition, there is a range of other Commonwealth and Queensland legislation relevant to management of the GBR. Management is also guided by Australia's obligations under relevant international conventions.

The legislation and conventions relevant to the Region are listed below:

Great Barrier Reef Marine Park legislation
Great Barrier Reef Marine Park Act 1975 is the primary Act in respect to the Great Barrier Reef Marine Park.

- 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 Marine Park Zoning Plan 2003 is the primary planning instrument for the conservation and management of the Marine Park.
- Cairns Area Plan of Management 1998, and Hinchinbrook Plan of Management 2004 establish more detailed management arrangements for specific areas of the Marine Park.

Other Commonwealth legislation

- Environment Protection and Biodiversity Conservation Act 1999 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.
- 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
- Sea Installations Act 1987 regulates the installation of structures including tourism pontoons and power cables

Queensland legislation

- Coastal Protection and Management Act 1995
- Environmental Protection Act 1994
- Environmental Protection Policy (Water) 2009
- Fisheries Act 1994
- Local Government Act 1993
- Marine Parks Act 2004
- Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004
- Native Title (Queensland) Act 1993
- Nature Conservation Act 1992
- State Development and Public Works Organisation Act 1971
- Sustainable Planning Act 2009
- Transport Operations (Marine Pollution) Act 1995
- Transport Operations (Marine Safety) Act 1994
- Transport Infrastructure Act 1994
- Vegetation Management Act 1999

- Water Act 2000
- Workplace Health and Safety Act 1995

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
- United Nations Framework Convention on Climate Change, 1992

Appendix 2: Experts involved in the INFFER workshops and review of the WQIP

Project team	Organisation	Contribution to WQIP
Geoff Park	Natural Decisions	INFFER analysis, NRM decision support systems
Jane Waterhouse	C_2O Consulting, TropWATER	WQIP Coordinator Water quality risk assessment
Peter Bradley	Terrain	WQIP Coordinator
Fiona Barron	Terrain	WQIP Coordinator
Jon Brodie	TropWATER	Ecologically relevant targets, water quality risk assessment
Steve Lewis	TropWATER	Ecologically relevant targets, pesticide risk assessment, pollutant analysis
Neil Sing	Terrain	Agricultural management practice synthesis
Marcus Smith	DAFF	Management practice economics
Jo Johnson	C_2O Consulting	Coastal and marine status and trends
John Armour	DNRM	Banana management practices, Source Catchments load modelling
Louise Hateley	DNRM	Source Catchments load modelling
Ryan Turner	DSITIA	Establishment of Russell-Mulgrave end of catchment monitoring
Colette Thomas	TropWATER	Marine ecosystem values
Len McKenzie	TropWATER	Seagrass monitoring review
Paul Groves	GBRMPA	Coastal ecosystem assessment and BlueMaps
Donna Audas	GBRMPA	Coastal ecosystem assessment and BlueMaps
Travis Sydes	FNQROC	Catchment waterways management prioritisation
Frederieke Kroon	CSIRO	Freshwater condition and trend assessment
Brendan Ebner	CSIRO/TropWATER	Freshwater condition and trend assessment
James Donaldson	CSIRO	Freshwater condition and trend assessment
Richard Brinkman	AIMS	Linkages between Crown of Thorns Starfish and rivers
Britta Schaffelke	AIMS	Linkages between Crown of Thorns Starfish and rivers
Scott Wooldridge	AIMS	Ecologically relevant targets for DIN
Ian Little		Upper Herbert sediment sources assessment
Bernie English	DAFF	Upper Herbert sediment sources assessment
David Logan	Healthy Waterways	Urban WQIP framework and management practices
John Gunn	Earth Environmental	Urban WQIP framework and management practices
Terrain NRM staff		**Role**
Michael Nash		
Deb Bass		
Bruce Corcoran		
Gavin Kay		
Alex Knott		
Deb Harrison		
Ian Sinclair		
Tony O'Malley		
Jacqui Richards		
Don Pollock		
Lyle Johnson		
Steve McDermott		
Bart Dryden		
Penny Scott		
Carole Sweatman		

Policy and stakeholder representatives	**Organisation**	**Comment**
Georgina Newton	DoE	*First workshop only*
Ashleigh Croxford	DoE	*First workshop only*
John Bennett	DEHP	
Phil Hales	DAFF	
Matt Kealley	Canegrowers	*Unable to attend workshops*
Sean Hoobin	WWF	
Glen Holmes	WWF	
Carol Honchin	GBRMPA	
Hugh Yorkston	GBRMPA	
Peter Gibson	NQDT	

Appendix 3: Summary of pollutant loads for the Wet Tropics NRM region.

Source: Hateley et al. (2014) and Brodie et al. (2014).

Table 1. Suspended sediment loads ($kt.y^{-1}$) for the Wet Tropics Basins with the 2018 Reef Plan target (20% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	20% target reduction of anthropogenic load	Target	Total Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	44	62	19	4	59	61	5.4%	27.1%
Mossman	507,886	7	14	7	1	13	14	9.9%	49.4%
Barron	793,802	42	92	50	10	82	82	19.8%	99.0%
Mulgrave-Russell	3,684,046	67	168	101	20	148	150	17.9%	89.3%
Johnstone	4,559,029	88	265	178	36	230	236	16.5%	82.6%
Tully	3,488,088	46	110	64	13	97	104	9.0%	44.8%
Murray	1,290,985	21	43	22	4	39	40	13.3%	66.5%
Herbert	4,273,490	130	463	333	67	396	434	8.6%	43.2%

Table 2. Dissolved Inorganic Nitrogen loads ($t.y^{-1}$) for the Wet Tropics Basins with the 2018 Reef Plan target (50% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	50% target reduction of anthropogenic load	Target	Total - Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	323	387	64	32	355	379	11.8%	23.6%
Mossman	507,886	55	107	52	26	81	101	12.4%	24.8%
Barron	793,802	47	90	43	22	68	89	2.0%	4.0%
Mulgrave-Russell	3,684,046	438	695	258	129	567	652	16.9%	33.9%
Johnstone	4,559,029	506	1,360	854	427	933	1,304	6.5%	13.1%
Tully	3,488,088	344	702	358	179	523	686	4.3%	8.6%
Murray	1,290,985	166	288	122	61	227	273	12.1%	24.2%
Herbert	4,273,490	535	807	272	136	671	695	41.2%	82.4%

Table 3. Particulate Nitrogen loads (t.y^{-1}) for the Wet Tropics Basins with the 2018 Reef Plan target (20% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	20% target reduction of anthropogenic load	Target	Total - Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	195	282	86	17	264	279	3.7%	18.3%
Mossman	507,886	34	59	25	5	54	56	10.2%	51.0%
Barron	793,802	66	182	116	23	159	173	7.3%	36.6%
Russell-Mulgrave	3,684,046	276	559	284	57	503	521	13.6%	68.2%
Johnstone	4,559,029	340	1,144	804	161	983	1,025	14.8%	74.1%
Tully	3,488,088	210	421	211	42	379	400	10.3%	51.3%
Murray	1,290,985	97	159	62	12	147	149	16.4%	82.2%
Herbert	4,273,490	319	1,038	719	144	894	987	7.2%	36.0%

Table 4. Dissolved Inorganic Phosphorus loads (t.y^{-1}) for the Wet Tropics Basins with the 2018 Reef Plan target (50% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	50% target reduction of anthropogenic load	Target	Total - Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	18	24	6	3	21	23	9.9%	19.9%
Mossman	507,886	3	5	2	1	4	5	19.6%	39.2%
Barron	793,802	5	12	7	4	9	12	0.5%	1.0%
Russell-Mulgrave	3,684,046	25	41	16	8	33	40	6.9%	13.9%
Johnstone	4,559,029	28	49	21	10	39	47	9.8%	19.6%
Tully	3,488,088	19	33	13	7	26	32	8.4%	16.8%
Murray	1,290,985	9	17	8	4	13	16	15.0%	29.9%
Herbert	4,273,490	30	47	17	8	39	45	10.2%	20.5%

Table 5. Particulate Phosphorus loads (t.y^{-1}) for the Wet Tropics Basins with the 2018 Reef Plan target (20% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	20% target reduction of anthropogenic load	Target	Total - Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	41	57	16	3	54	54	15.3%	76.5%
Mossman	507,886	7	14	7	1	12	12	27.3%	136.7%
Barron	793,802	23	67	43	9	58	59	18.3%	91.4%
Russell-Mulgrave	3,684,046	65	175	110	22	153	152	21.1%	105.6%
Johnstone	4,559,029	104	453	349	70	383	352	28.7%	143.7%
Tully	3,488,088	44	110	66	13	97	98	18.5%	92.3%
Murray	1,290,985	20	46	26	5	40	39	26.1%	130.5%
Herbert	4,273,490	97	377	280	56	321	353	8.8%	43.8%

Table 6. PS-II herbicide loads (kg.$^{y-1}$) for the Wet Tropics Basins with the 2018 Reef Plan target (60% reduction).

Basin	Mean Annual Flow ML/yr Baseline	Pre-Development	Total Baseline (08/09)	Anthropogenic Baseline load	60% target reduction of anthropogenic load	Target	Total) - Report Card 2013	% reduction from anthropogenic	% of target achieved
Daintree	2,639,319	0	235	235	141	94	192	18.5%	30.9%
Mossman	507,886	0	150	150	90	60	119	20.9%	34.8%
Barron	793,802	0	269	269	162	108	239	11.1%	18.5%
Russell-Mulgrave	3,684,046	0	1,482	1,482	889	593	1,114	24.8%	41.4%
Johnstone	4,559,029	0	1,861	1,861	1,117	744	1,264	32.1%	53.5%
Tully	3,488,088	0	1,359	1,359	815	544	1,000	26.4%	44.0%
Murray	1,290,985	0	862	862	517	345	590	31.6%	52.6%
Herbert	4,273,490	0	2,378	2,378	1,427	951	1,850	22.2%	37.0%

Appendix 4: Wet Tropics NRM Region ABCD Management Practice Framework

Source: Sing and Barron (2014)

The following ABCD frameworks are those determined as suitable for use over the next five years. The previous one is Sing and Barron (2014) (Appendix). They replace the frameworks used over the last five years which have been superseded by improved practices or improved data collection requirements. Even so many practices remain the same.

They have been grouped by pollutant so for example CN 1.0 refers to cane – nutrients, CS 16.0 refers to Cane - sediment. They were determined by building up on the previous ABCD using the Terrain Technical Group to make decisions about the appropriate changes to be made. New research was taken into account. Unlike the RR1 ABCD all tables included are hierarchical and set up so that an answer can be supplied by all farmers even if just "Not Applicable".

The levels of practice below have introduced a new term to the ABCD framework being U for unproven. Too many farmers were assuming that A must be the best practice but by definition A practices are largely unproven even though scientific opinion believes it is likely to be the best practice. The use of U or unproven is an attempt to emphasis this feature of A level practices.

The Management Approach, termed Investment or Extension, refers to the activity that is recommended to obtain changes in management practices.

Cane

NUTRIENT MANAGEMENT

CN1.0 Soil testing **Management Approach: Extension**

Level	Practice
U/A	Soil testing in specific areas within blocks at least once per crop cycle in relation to soil and yield mapping
B	Soil testing at least once per crop cycle for every plant cane block irrespective of soil type
C	Soil testing once per crop cycle per soil type
D	Soil testing not done

CN2.0 Nutrient rate assessment **Management Approach: Extension**

Level	Practice
U/A	Develop GIS based nutrient management plan using yield potential, soil mapping and specialist interpretation of latest industry recommendations including the use of slow release fertilisers
B	Completed Six Easy Steps (6ES) and developed and implemented a nutrient management plan (NMP) and associated recommendations
C	Use latest industry recommendations (6ES) based on advice (No NMP)
D	Application rates not in line with 6ES

CN3.0 Rate of fertiliser use **Management Approach: Extension & Investment**

Level	Practice
U/A	Variable rate within Blocks based on all 6 components of 6ES and where the basis of variability in the block is accurately identified.
B	Variable Rate between Blocks based on all 6 components of 6ES
C	One rate for plant and another for ratoon based on 6ES
D	One fixed rate for plant and one for ratoons based on historic application rates or rule of thumb

CN4.0 Timing of fertiliser application Management Approach: Extension

Level	Practice
U/A	Climate forecasting (i.e. 2-3 months ahead) used in determining the timing and amount of fertiliser applied
B	Timing of nutrient applications with respect to proximity to the start of the wet season, crop stage, irrigation and weather conditions
C	Follows weather (i.e. 4-5 days ahead) but does not consider crop stage or time of year.
D	Weather only impacts on ability to do application at the time.

CN5.0 Placement of fertiliser Management Approach: Extension & Investment

Level	Practice
U/A	
B	Sub-surface applied within the stool by stool-splitter or similar modified equipment.
B	Sub-surface applied beside the stool (or surface applied on the row, only where rocks or other block characteristics prevents subsurface application).
C	Surface applied, on the row only
D	Surface applied using broadcasting methods

CN29.0 Placement of fertiliser (overhead irrigation only) Management Approach: Investment

Level	Practice
U/A	Apply N fertiliser via the irrigation water (fertigation) using split applications.
B	Apply a single application of N fertiliser subsurface either within the stool or beside the stool
C	Band a single application of N fertiliser over the stool
D	Broadcast a single application of N fertiliser

CN6.0 Calibration of fertiliser applicator Management Approach: Extension & Investment

Level	Practice
A	Calibrated electronic rate controller used and outputs monitored
B	Calibrates for each product and batch and monitors application
C	Calibrates once per season for each fertiliser product
D	No calibration of equipment done

CN31.0 Application of mill-mud/ash Management Approach: Investment

Level	Practice
U/A	Variable-rate mill mud application at less than 100t per ha using GPS and site-specific application. Applied to stool only, when used in ratoons or plant.
B	Variable-rate mill mud application at less than 100t per ha. Applied to stool only when used in ratoons or plant.
C	Application with or without rate control at rates lower than 100 tonne per ha
D	Application without rate control and at rates over 100t per ha
N/A	Does not apply mill mud on farm

CN8.0 Managing Legume Nitrogen Contribution Management Approach: Extension & Investment

Level	Practice
U/A	Leaves legume stubble standing and direct drills plant cane
B	Spray out/slash legume crop and residue left on the surface until preparing for planting. May include mulching depending on degree of .
C	Mulching or discing-in of legume crop just prior to planting.
D	Legumes disced in weeks before planting
N/A	Fallows but does not use legumes
N/A	Does not usually have a fallow area

WEED MANAGEMENT

CP10 Residual Herbicide use in plant cane Management Approach: Extension

Level	Practice
U/A	Residual herbicides used sparingly and in conjunction with sophisticated weather forecasting to avoid use close to heavy rainfall events. Herbicides (& their break-down products), with proven lower toxicity and shorter half-lives, are used instead wherever possible.
B	Residual herbicides are applied with extra caution after October to avoid use close to heavy rainfall events. Herbicides (& their break-down products), with proven lower toxicity and shorter half-lives, are used instead wherever possible.
C	Residual herbicide applied at rates appropriate to weed size and type, but applied right up to the commencement of the wet season
D	Residual herbicide applied at full label rates and whenever convenient rather than in response to weed size & type or timing of the wet-season

CP33 Residual Herbicide use in ratoons Management Approach: Extension

Level	Practice
U/A	Residual herbicide not applied to ratoon crops at all
B	Residual herbicide only used in ratoons on problem blocks & on less than 10% of total ratoons area.
C	Residual herbicide applied only once on each ratoon crop with knockdowns used at other times
D	Residual herbicide being applied whenever seen as likely to be effective.

CP34 Knockdown Herbicide used in plant cane Management Approach: Extension & investment

Level	Practice
U/A	Weed recognition on all spray equipment allowing targeting of particular weeds with relevant chemicals.
B	Broadleaf weeds & grasses targeted separately by sprayer with two tanks & directed sprays.
C	Whole area of plant cane sprayed with broad-spectrum brew covering broadleaf’s and grasses

CP35 Knockdown use in ratoons Management Approach: Extension & Investment

Level	Practice
U/A	Weed recognition on all spray equipment allowing targeting of particular weeds where relevant
B	Broadleaf weeds & grasses targeted separately by sprayer with two tanks & directed sprays.
C	Whole area of ratoon cane sprayed with broad-spectrum brew covering broadleaf and grasses

CP12.0 Herbicide Application Timing Management Approach: Extension

Level	Practice
U/A	Timing of herbicide application as in ‘C’ below, in conjunction with best available long-term weather forecasting to avoid or minimize use of residual herbicides within 30 days of the onset of the wet-season.
B	Timing of herbicide applications as in ‘C’ below, in conjunction with short-term weather forecasting (7+ days) to avoid application close to heavy rainfall events.
C	Timing of herbicide applications with regard to eg:, • crop stage • weed size, • soil-moisture • trash & canopy cover • temperature • irrigation but only taking weather conditions at the time into account
D	Applies at a time when it has become a salvage operation

CP14.0 Calibration **Management Approach: Extension and investment**

Level	Practice
A	Calibrated electronic rate-controlled equipment used with latest application technology such as air inducted nozzles.
B	Manually calibrated for each situation (product and water rate) with appropriate nozzles and technology.
C	Regular calibration and maintenance of equipment
D	Occasional calibration and maintenance of equipment

CP36 Spraying equipment **Management Approach: Extension & Investment**

Level	Practice
U/A	Precision spot-spraying using image analysis for weed recognition. Likely includes use of GPS guidance.
B	Uses directed sprays or hoods and two tanks with separate application capacity to control weeds.
C	Uses boom spray for all spraying operations with residual/knockdown mix but targets weeds by block
D	Uses boom spray for all spraying operations with only one tank and applies mixes to whole farm.

CP37 Weed control in the fallow – flooding likely **Management Approach: Extension**

Level	Practice
U/A	
B	Spray out cane & retain trash blanket. Continued weed control (spray) when necessary.
C	Mechanical plough-out followed by grassy fallow.
D	Mechanical plough-out and maintain bare fallow.
N/A	No fallow

CP38 Weed control in the fallow – flooding unlikely **Management Approach: Extension**

Level	Practice
U/A	Spray out cane and direct drill with legumes. Continued weed control within legume crop.
B	Zonal-till old stool prior to zonal planting of legumes. Continued weed control within legume crop
C	Cultivate block then plant legumes.
D	Bare or Grassy Fallow
NA	No fallow used

SOIL MANAGEMENT

CS16.0 Row spacing (compaction) **Management Approach: Investment**

Level	Practice
U/A	Controlled traffic > 1.75m with GPS guidance on all equipment used in the paddock (including harvester and haul outs)
B	Uses row-spacing between 1.65 and 1.75 with GPS
C	Uses row spacing between 1.65 m and 1.75m without GPS
D	Uses row spacing below 1.65m

CS39.0 Planting Method **Management Approach: Extension & Investment**

Level	Practice
U/A	Cane Planted using GPS guided, zero till, disc-opener cane planting (DOP). No subsequent cultivation.
B	Cane Planted into zonal-tilled row regardless of planter type (conventional, mound, DOP), with or without GPS.
C	Cane planted after minimum till across whole paddock (<5 passes) regardless of planter type,
D	Cane planted after full cultivation across whole paddock (>5 passes), regardless of planter type.

CS17.0 Cultivation prior to planting **Management Approach: Investment**

Level	Practice
U/A	Zero till plant cane
B	Renovates permanent beds followed by zonal tillage before planting
B	Zonal tillage before planting
C	Reduced tillage before planting (< 5 times)
D	Fully cultivated before planting (> 5 times)

CSL19.0 Legume Establishment Practices **Management Approach: Investment**

Level	Practice
A	Zero till legume fallow (using direct-drill legume planter)
B	Zonal-till legume fallow
C	Fully cultivated legume fallow on beds.
D	Fully cultivated, broad-spread legume fallow
N/A	Do not use legumes

CSNL19.0 Non legume fallow practices **Management Approach: Extension**

Level	Practice
B	Stools sprayed-out, grassy fallow, on country that floods
C	Stools sprayed out, grassy fallow on country that does not flood
D	Cultivated bare fallow
N/A	Uses legume fallow
N/A	No fallow
N/A	Rotate with other crops on the farm

Q 24 CS20.0 Plough out replant policy **Management Approach: Extension**

Level	Practice
B	Plough out replant not used
C	Occasionally use plough out replant as a practice
D	Continual plough out replant used as a routine practice on most of farm

CS21.0 Riparian management **Management Approach: Extension & Investment**

Level	Practice
U/A	Native Riparian vegetation at 20m wide for creeks and 50m for major waterways along 100% of the length of all sides of all natural waterways managed by you.
B	Native Riparian vegetation at <20m wide along 100% of the length of natural waterways managed by you.
C	Riparian vegetation on >50%, but <100% of the length of natural waterways, managed by you.
D	Riparian vegetation along natural waterways is sparse or non existent
N/A	No natural waterways on farm

CSST22.0 Sediment risk management tools – silt traps **Management Approach: Investment**

Level	Practice
B	Silt traps designed and used in appropriate locations on farm, based on professional advice.
C	Silt traps are used to capture some sediment. Some sediment loss in heavy rainfall events still occurs.
N/A	Not relevant on my farm

CS40.0 Headland Management **Management Approach: Extension**

Level	Practice
B	All headlands are >5m wide, grassed, shaped and maintained to control water shedding, erosion and nutrient transport.
C	Headlands grassed and maintained to minimise erosion.
D	Headlands are eroding and /or have poor groundcover.

CSSD22.0 Shallow drains **Management Approach: Investment**

Level	Practice
A	All farm drains engineered and maintained to minimize erosion including large and common drains. (grassed or armoured)
B	All shallow drains are spoon type where topography allows, are grassed and maintained.
C	Some shallow box drains on the farm needing battering or changing to a spoon drain
N/A	Not relevant on my farm

CSDP22.0 Deep drains **Management Approach: Investment**

Level	Practice
A	All farm drains engineered and maintained to minimize erosion using vegetation or rock.
B	All deep drains on farm are battered and stable through the use of rock armouring or vegetation.
C	Some deeper box drains on the property needing attention
N/A	Not relevant on my farm

CR24.0 Record keeping **Management Approach: Extension & Investment**

Level	Practice
U/A	As in B below, but including automated field data collection from tractor-mounted computers/controllers with associated recording and reporting functions.
B	Detailed computer-based records of field activities, farm inputs production results and monitoring data (eg soil analyses, weed-survey, water-quality) & any nutrient/weed management plans
C	Detailed paper-based records of field activities & inputs (eg nutrient rates in kg/ha, types & rates of herbicides etc) as well as mill-supplied production records

CN 25.0 Irrigation scheduling **Management Approach: Investment**

Level	Practice
U/A	Use a tool such as "WaterSense" to integrate factors such as climatic conditions, soil PAWC & crop development to estimate daily crop water use and determine the weekly irrigation requirement for each individual block
B	Use objective tools such as capacitance probes, tensiometers, gypsum blocks &/or evaporation pans to directly or indirectly measure changes in soil moisture to determine the weekly irrigation requirement for individual or multiple blocks (e.g. whole farm)
C	Use subjective tools such as visual inspection of crop &/or soil to determine a need for irrigation
D	Irrigation scheduled depending on water availability or set time cycle (e.g. time taken for irrigator to complete full cycle around farm)

CN26.0 Furrow design (applicable to furrow irrigation only) Management Approach: Investment

Level	Practice
U/A	Appropriate furrow shape, slope and length determined for each block using "SIRMOD". Land forming carried out with laser guided machinery
B	Laser guided land forming used to modify slope to industry recommendations based on soil type. Furrow shape & length modified to industry recommendations depending on soil type
C	Slopes modified by land forming (not laser guided). Furrow shape and length not altered for different soil types
D	No land forming carried out and furrow shape and length not altered for different soil types

CN27.0 Irrigation distribution uniformity

(re: overhead irrigation only) Management Approach: Investment

Level	Practice
U/A	Distribution uniformity greater than 90%
B	Distribution uniformity between 75% - 90%
C	Distribution uniformity between 60% - 75%
D	Distribution uniformity less than 60%

CN28.0 Recycle strategy **Management Approach: Investment**

Level	Practice
U/A	Recycle pit on suitable soils or materials, with first flush capture of water overflow
B	All of farm water recycling strategy with a well designed recycle pit on suitable soils (or suitable materials).
C	No recycling

Bananas

SOIL MANAGEMENT

BS25.0 Cultivation method and timing – crop destruction

Level	Description of practice
B	The banana crop is removed by treating with herbicide and plants are left to break down before cultivation.
C	The banana crop is removed by mechanical practices with minimal soil disturbance eg light discing / mulching.
D	The banana crop is removed by heavy discing green plant material repeatedly.

BS1.0 Cultivation method and timing – land preparation

Level	Description of practice
A	Pre-formed beds using GPS & zonal-tillage.
B	The row only is cultivated at the times of the year when the risk of erosion is low.
C	The whole block is cultivated at the times of the year when the risk of erosion is low.
D	The whole block is cultivated at any time of the year.

BS26.0 Controlling run-off water - Contouring

Level	Description of practice
B	If the farm has areas under banana production with a gradient over 3%, all blocks have been planted along the contour and include diversion banks and constructed waterways which have been accurately surveyed.
C	If the farm has areas under banana production with a gradient over 3%, most blocks have been planted along the contour and include diversion banks and constructed waterways.
D	The farm has areas under banana production with a gradient over 3% but there are no control structures in place.
N/A	The farm does not have areas under banana production with a gradient over 3%.

BS2.0 Fallow / Crop rotation

Level	Description of practice
A	A planted fallow crop is grown between banana crop cycles, on all fallow land for a minimum of 12 months.
B	Either a grass fallow or a planted fallow crop is grown between banana crop cycles on all fallow land (for less than 12 months).
C	A weedy fallow grows between banana crop cycles.
D	There is no fallow period between banana crop cycles or bare fallow is left between crop cycles.

N/A	

BS27.0 Riparian Vegetation

Level	Description of practice
A	Native riparian vegetation at 20m wide for creeks and 50m for rivers along 100% of their length.
B	Native riparian vegetation is present at less than 20m wide for 100% of the length of all creeks and rivers.
C	Native riparian vegetation is present for at least 50% of the length of all creeks and rivers.
D	Native riparian vegetation is present for less than 50% of the length of all creeks and rivers.
N/A	No natural water ways on farm so no riparian vegetation.

BS28.0 Controlling run-off water – Silt traps

Level	Description of practice
B	Silt traps have been designed, constructed and located with expert advice and satisfactorily address the targeted sediment issue.
C	Silt traps have been designed, constructed and located with expert advice. , however some sediment loss indicates further work is still required.
D	Silt traps have been designed, constructed and located without expert advice.
N/A	No silt traps present on farm.

BS29.0 Controlling run-off water - Drains

Level	Description of practice
A	All constructed drains on-farm (deep or shallow) are vegetated spoon shaped drains.
B	Most constructed drains on-farm are vegetated-shallow-spoon drains and any box drains have a batter suited to the soil type so they do not erode.
C	Most constructed drains on farm are box drains with steep batters & little vegetative cover.
N/A	No constructed drains on farm.

BS30.0 Ground cover

Level	Description of practice
B (i)	At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, excluding major roadways.
B (ii)	In very dry areas only, where inter-row cover would have to be watered and where plant waste does not break down readily, greater than 60% inter-row ground-cover is achieved by retention & mulching of banana wastes.
C	At least 60% ground cover is achieved by a combination of living & dead matter in areas such as the inter-row space and headlands. This includes mulching banana plant material in the inter-row space, excluding major roadways.
D	Areas such as inter-rows and headlands are bare.

BS40.0 Mulching

Level	Description of practice.
B	Harvested heads and leaves are left on the row or in drier areas harvested heads are mulched in the inter-row space providing ground cover.
C	Harvested heads and leaves are left where they drop.
D	Harvested heads and leaves are removed from the row and placed in the inter-row space.

NUTRIENT MANAGEMENT

BN31.0 Soil testing pre-plant

Level	Description of practice
B	100% of blocks are soil tested before planting.
C	Most blocks are soil tested before planting.
D	Soil testing before planting is infrequent or not done at all.

BN32.0 Soil testing – ratoons

Level	Description of practice
A	Soil tests are taken on all blocks more than once a year.
B	Soil tests are taken on all blocks once a year.
C	Soil tests are taken less than once a year or on fewer than all blocks
D	No or little soil testing.

BN 33.0 Leaf testing

Level	Description of practice
B	Paired leaf and soil tests are taken on all blocks at least annually.
C	Paired leaf and soil tests are taken at indicator sites at least annually or tissue tests taken throughout the year but not paired with soil tests.
D	Leaf tests are taken less than annually or not at all.

BN34.0 Fertiliser program – selecting nutrient types and amounts (Nutrient rates)

Level	Description of practice
B	The fertiliser program is supported by soil and leaf testing and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.
C	The fertiliser program is supported by frequent soil and leaf testing and yield monitoring.
D	There is no planned fertiliser program and/or the rates applied are not based on soil and leaf test results.

BN35.0 Fertiliser program – nutrient budgeting

Level	Description of practice
B	The fertiliser program is based on recommended rates for nitrogen and phosphorus.
C	The fertiliser program is not based on recommended rates for nitrogen and phosphorus.

BN36.0 Fertiliser application frequency

Level	Description of practice
A	
B	Aim is to apply fertilizer fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.
C	Aims is to apply fertiliser monthly all year round.
D	Fertiliser is applied less frequently than monthly.

BN37.0 Fertiliser application method

Level	Description of practice
A	
B	All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.
C	Banded surface fertiliser applications to rows only.
D	Fertiliser broadcast over rows and inter-row spaces.

BN22.0 Water and fertiliser distribution efficiency

Level	Description of practice
A	
B	Water uniformity and distribution is tested and above 90%.
C	Water uniformity and distribution is tested and above 80% but below 90%.
D	Water uniformity and distribution is tested and below 80% or not tested and therefore unknown.

IRRIGATION
BN19.0 Method of Irrigation

Level	Description of practice
A	
B	100% under-tree sprinklers or drip and an automated system.
C	100% under-tree sprinklers or drip and a manual system.
D	Some overhead irrigation.

BN21.0 Soil moisture monitoring

Level	Description of practice
A	Irrigation schedules are based on capacitance probes and weather stations and are fully automated.
B	Irrigation schedules are based on capacitance probes or tensiometers and use a manual system.
C	Scheduling based on subjective tools e.g. feel, inspection of soil, water availability and area.
D	

INTEGRATED PEST & DISEASE MANAGEMENT
BP38.0 Pest & disease Monitoring

Level	Description of practice
A	
B	Pest and disease levels are monitored on a regular and consistent basis by trained staff or service providers. Records are retained and treatment are applied using monitoring information and relevant threshold levels for each pest/disease.
C	Pest and disease levels are monitored by general observations when doing other activities and control methods applied accordingly.
D	Pest and diseases are not monitored on a regular basis. Spray treatments are applied on a calendar basis or in response to severe outbreaks.

BP39.0 Pesticide Resistance

Level	Description of practice
A	
B	A rotation program is in place to ensure products are applied correctly and rotated according to label instructions, to prevent resistance from developing.
C	Attempts are made to rotate between chemical groups according to label instructions, but there is no effective rotation program in place.
D	Chemicals are not rotated to avoid resistance.

GENERAL

BP16.0 Disposal of shed water

Level	Description of practice
A	Settlement and filtration ponds used to remove all extraneous material including post harvest chemicals before release into local waterways.
B	Filtration in place to remove fine particles and larger debris before releasing water into local drains or waterways.
C	Grates in the shed to remove large debris before water is released into local drains or waterways.
D	No filtration of any sort in place and water from the packing shed is disposed of into adjacent drainage lines or waterways.

BR23.0 Record keeping

Level	Description of practice
A	As in B below, but including automated field data collection from tractor-mounted computers/controllers with associated recording and reporting functions.
B	Detailed computer-based records of field activities, farm inputs, production results and monitoring data (eg soil analyses, weed-survey, water-quality) & any nutrient/weed management plans
C	Detailed paper-based records of field activities & inputs (eg nutrient rates in kg/ha, types & rates of herbicides etc) as well as production records
D	Pocket diary of a limited range of farm operations.

Tableland Mixed Cropping

NUTRIENT
Soil Mapping

Level	Description of practice
A	Completed soil survey/tests of property to ascertain soil properties and management zones, and mapped to GIS & managed accordingly
B	Aware of different soil zones on property and has a management strategy for each block
C	Knows of different soils on the property but uses a single management strategy.
D	Have not yet investigated the impact of soil types on management
N/A	Investigations have shown soils on property all the same type

Soil testing

Level	Description of practice
A	Nutrients applied at variable rates based on soil analysis targeting identified zones within a paddock before planting
B	Nutrient application rates based on soil samples for each soil type, and the place in rotation
C	Nutrient application rates based on occasional soil samples for whole farm before planting, and knowledge developed from experience
D	Nutrient rates are based on previous experience

Fertiliser application

Level	Description of practice
A	
B	If irrigated crops' fertiliser applied in multiple applications through irrigation/fertigation system weather permitting or banded surface when not
B	If dry land (rain grown) then fertiliser applied as basal underground then topdressing banded in a granulated form
B	If rain grown grass crops part of rotation then broadcast in granulated form
C	If irrigated the basal fertiliser is placed in banded application in granulated form underground with topdressings surface banded.
D	Fertiliser is broadcast on the surface over whole paddock in granulated form

SEDIMENT
Sediment risk management

Level	Description of practice
A	Farm water flows mapped as part of sediment loss management with control measures such as contour banks, grassed headlands, grassed waterways and riparian areas in place and monitor sediment loss
B	Aware of potential erosion areas on farm and have implemented control measures such as slashing grassed headlands and maintaining contour banks
C	Eroded areas repaired after major water events, to limit further damage
D	Soil loss from the farm is not a significant issue even though some blocks are over 3%
N/A	All blocks have less than 3% slope so soil loss rarely occurs

Grassed headlands

Level	Description of practice
A	Grassed headlands surround all blocks and maintained by slashing (only where 65% ground cover can be achieved at all times of the year)
B	Grassed headlands largely only on bottom of all blocks with over 3% slope and maintained by slashing & not sprayed out
C	Headlands are a mix of grassed, cultivated and spray out
D	Headlands either sprayed out or cultivated or do not exist.

N/A	Not possible to maintain 65% grass cover because of the dry climate where farm is located

Contour banks

Level	Description of practice
A	
B	Contour banks on all blocks with >3% slope assessed annually & renovated as required to control water flows with outlets into grassed headlands or grassed waterways
C	Contour banks used on some blocks >3% but not all blocks and renovated occasionally to control water flows out flowing onto headlands
D	No contour banks used or contour banks exist on farm but are not maintained or taken into account in farming operations
N/A	Slope of all blocks all under 3% so contour banks not required.

Riparian management

Level	Description of practice
A	Natural waterways are bound by riparian vegetation extending 10m from the top of the bank
B	Natural waterways are bound by riparian vegetation extending 5m from the top of the bank
C	Natural water ways have some sections that are vegetated with a few trees
D	Riparian plantings along natural waterways regarded as a hindrance
N/A	No natural waterways on farm

Cultivation to control sediment loss – all crops except potatoes

Level	Description of practice
A	Controlled traffic farming with permanent/semi-permanent beds with zero or zonal tillage
B	Minimal tillage cultivation 3X or less using vertical tillage tools only (e.g. chisel plough, disc harrow etc) with a GPS
C	Tillage operations incorporating horizontal (plough or rotary hoe) & vertical tillage equipment 4 or less cultivations
D	Full conventional tillage operation seen as preferable

Cultivation to control sediment loss – potatoes

Level	Description of practice
A	
B	One crop in three rotation practiced using a rotary hoe & vertical equipment plus a GPS
C	Tillage operations incorporating horizontal (plough or rotary hoe) & vertical tillage equipment 4 or less cultivations
D	Full conventional tillage operation seen as preferable
N/A	Does not grow potatoes

Compaction

Level	Description of practice
A	Machinery guided by GPS with RTK accuracy to maintain traffic to permanent lanes between beds.
B	Trafficked areas are limited to set laneways and roads with a GPS to limit compaction.
C	Attempts to reduce machinery traffic as much as possible. (no GPS)
D	Soil compaction not an issue on my farm

Fallow practice

Level	Description of practice
A	Rain grown mixed cover crop used
B	Rain grown single cover crop grown to limit erosion risks and add organic matter
C	Farm has crop stubble left after harvesting & not baled to control wind erosion and add organic matter to soil
D	Fallow crops not part of rotation or bare fallow used and any stubble baled

Use of contours & drainage

Level	Description of practice
A	Blocks contoured and terraced (where applicable) with run off directed to sediment retention structures where slope is >5%. All farm operations align with the contour and drains are spoon type, grassed, and slashed at least 3 times a year and follow contours where appropriate.
B	Working over the contour with water running along the contour into contoured drains that are spoon type, grassed, and slashed up to 3 times a year
C	Water runs down row, off onto headlands and then into drains which are spoon type, grassed, and slashed up to 1-2 times a year; with contours used on a few blocks
D	Water runs down the row and off onto headlands and then into drains that are not always grassed and contours not significant.

Irrigation Scheduling

Level	Description of practice
A	Scheduling based on use of objective tools (e.g. capacitance probes, tensiometers, weather stations, evaporation pans) & yearly assessment of crop water requirement based on historical and projected weather conditions/climate forecasting
B	Scheduling based on use of objective tools (e.g. capacitance probes, tensiometers, weather stations, evaporation pans) only
C	Scheduling based on subjective tools (e.g. finger, shovel, push rod, wilting)
D	Irrigate on a calendar basis for a set time

Water Distribution

Level	Description of practice
A	
B	Water distribution uniformity consistently above industry benchmark (typically >90%DU) when tested every three years
C	Water distribution uniformity at industry benchmark (80-85% DU) tested occasionally
D	Water distribution uniformity may be below industry benchmark (80% DU) as only tested on establishment

PESTICIDE

Equipment

Level	Description of practice
A	Targeted application of chemicals using GPS or weed sensors, combined with the appropriate nozzles which are checked at least every 40 hrs of use
B	Use spray unit with nozzles appropriate to chemical and application job with GPS assisted rate controller & nozzles checked 3X yr
C	Use spray unit with appropriate nozzles that are checked annually and changed when required, to maintain effectiveness with ground or standard rate controller
D	Use spray unit with appropriate nozzles that are changed when required, to maintain effectiveness

Calibration

Level	Description of practice
A	
B	Calibration linked to flow meter with volume tested for efficacy of application
C	Rate controller calibrated
D	Equipment calibrated annually

Chemical application

Level	Description of practice
A	
B	Chemicals applied based on frequent monitoring of pest and weed incidence and size using an IPM approach taking into account the weather (DELTA T) and irrigation schedule
C	Chemicals applied on frequent monitoring of pest and weed incursions and taking the weather into account.
D	Chemicals applied based on some evidence of pest and weed incursions

Record keeping

Level	Description of practice
A	Complete records of chemical application, pest and disease incidence, application rate, location, wind speed etc, linked to GPS/GIS system and automated where possible through hand held or tractor input
B	Mix of computerised and paper records kept of all farm data including chemical and fertiliser type, rates and purpose, usually in paddock diary.
C	Paper based records of most farm physical data
D	Pocket diary of a limited range of farm operations

Grazing

The ABCD for grazing is that used in Reef Rescue I as no changes were made for Reef Rescue II (Reef Programme). This is because the ABCD was found to be an inadequate measure of any changes in stocking rate occurring as a result of any moves from C to B in any practices described in the ABCD framework. In the Reef Plan Scientific Consensus Statement 2013 it states that the biggest factor affecting sediment loss in the dry areas was vegetation cover but the ABCD framework for grazing was a poor measure of this feature. Consequently specific graziers are being targeted to reduce stocking rates in Reef Programme so the ABCD framework is not used.

Appendix 5: Water Quality Improvement Actions for Developing and Mature Urban Environments

J Gunn (2014): Urban Land Use in Great Barrier Reef Water Quality Improvement Plans: Background Report and Considered Guidance. Earth Environmental. Commissioned by RUSMIG.

The information presented here is drawn from Gunn (2014). The frameworks for developed areas (shown in Figure 1 and incorporating private and public sectors as the developer, and public sector as the development regulator), plus the mature urban framework and actions are included below.

State Legislation

Private sector
(see Table 1)

Concept design and planning
- Water sensitive urban design is incorporated at earliest stages
- An integrated open space and stormwater management approach is adopted

Development application
- All relevant matters are adequately addressed in the development application

Implementation
- SBSMPs and ESC are properly implemented
- WSUD measures are installed in accordance with design specifications
- Maintenance is responsive to the site and meets development approval conditions and succession planning

Notes: WSUD is water sensitive urban design. DA is development approval. ESC is erosion and sediment control. SBSMP is site based stormwater management planning. SPP is state planning policy.

Public sector[1] – (as development regulator)
(see Table 2)

Supporting policy and culture
- Strategic plan/s includes ecological sustainability principles,
- Adaptive, catchment-based total water cycle management approach within an ethos of environmental and social stewardship.

Legislative planning instruments (local/state)
- Regional plan;
- State Planning Policy;
- Planning scheme;
- Planning scheme policy.

Development assessment process
- Comprehensive guidance material available (internal and external);
- Clear, unambiguous assessment process;
- DA condition determination;
  - Staff competency,
  - Open to innovative solutions,
  - Negotiated outcomes possible including net gain environmental offsets.
  - DA conditions include,
    - Compulsory site based stormwater management planning incorporating site specific Best Practice erosion and sediment control measures to meet SPP,
    - WSUD measures to meet SPP,
    - Compliance self-assessment options as appropriate.

Compliance monitoring
- Responsive monitoring
- Compliance includes education, mentoring and training as the first option. Warning and enforcement action follows.

Evaluation and improvement
- Ongoing review of processes for;
  - Development assessment,
  - Compliance monitoring.
- Ongoing capacity building.

Reporting (links to external processes)

Public sector[2] – (as developer)
(see Table 3)

Supporting policy and culture

Planning phase
- Comprehensive guidance material available to staff including for,
  - Concept design,
  - Site based stormwater management planning (SBSMP),
  - Erosion and sediment control (ESC) as part of SBMPs,
  - Risk assessment,
  - Implementing SBSMPs and ESC.
- Implementation phase;
  - Staff competency includes appropriate training, capacity building and site inductions (internal),
  - Compliance monitoring,
  - Performance evaluation, reporting and improvement.

Notes: [1] applies mostly to local government. Where applicable substitute local planning instruments for state planning instruments or visa versa. [2] May be local or state government depending on the type of development or infrastructure being constructed.

Figure 1. Developing Urban Areas ABCD System Components.

Table 1. Draft Local Government Development Regulator/Manager ABCD.

Water Quality Improvement Activity	Class
Policy, Planning and Partnerships	
Policy and strategic planning	
Council actively supports catchment-based total water cycle management as a pathway for water quality and ecosystem health protection and improvement and this is reflected in its policies, strategies and initiatives which are resourced and implemented in partnership with all relevant stakeholders to accelerate water quality improvement outcomes	**A**
Council acknowledges the need for a catchment-based total water cycle management approach to water quality and ecosystem health improvement and its policy supports the achievement of water quality improvement over time with available resources	**B**
Council policy acknowledges the need for total water cycle management and ecosystem health protection in partnership with other stakeholders	**C**
Council acknowledges the need for other stakeholders to improve water quality and ecosystem health	**D**
A catchment management plan (as per the NWQMS), water quality improvement plan (WQIP) (as per Reef Plan 2003), total water cycle management plan (TWCMP) (as per the previous EPP Water including USQMP), healthy waters management plan (HWMP) (as per current EPP Water) or similar strategy plan prepared in conjunction with relevant stakeholders linking; flood mitigation, water sensitive urban design (WSUD), stormwater management (including erosion prevention), waterway management, potable water supply, wastewater treatment and water conservation with the protection of natural assets, environmental infrastructure, hydrological and ecological functions and ecosystem services	**A**
A catchment management plan, WQIP, TWCMP, HWMP or similar strategy plan prepared in conjunction with relevant stakeholders incorporating; flood mitigation, water sensitive urban design (WSUD), stormwater management (including erosion prevention), waterway management, wastewater treatment and water conservation	**B**
A catchment management plan, WQIP, TWCMP, HWMP or similar strategy plan prepared incorporating; flood mitigation, stormwater system management and water conservation	**C**
No catchment-based strategic water quality improvement plans prepared	**D**
An Urban Stormwater Quality Management Plan (USQMP) prepared by Council for mature urban areas, as a component of a WQIP, TWCMP, HWMP or similar, that links with and comprehensively integrates succession planning for environmental infrastructure from developing areas	**A**
USQMP prepared by Council for mature urban areas, as a component of a WQIP, TWCMP, HWMP or similar, and links with and/or integrates succession planning for developing areas	**B**
USQMP prepared by Council as per the EPP Water (now superseded)	**C**
No USQMP, or similar, prepared by Council	**D**
Strategic landscape and comprehensive local scale mapping prepared for planning and decision making including for identification and prioritisation of areas for location of protection mechanisms and treatment measures for maximum water quality improvement benefits and outcomes	**A**
Strategic landscape and local scale mapping prepared for planning and decision making including for identification and prioritisation of areas for location of protection mechanisms and treatment measures for water quality improvement	**B**
Strategic landscape scale mapping prepared for planning and decision making for initial identification of areas for location of protection mechanisms and treatment measures for water quality improvement	**C**
Acknowledged need for mapping to inform planning and decision making for water quality improvement	**D**
Council stormwater quality service levels reflect best practice for water quality improvement, exceed legislative requirements and are incorporated in strategic infrastructure planning	**A**
Council stormwater quality service levels agreed to meet or exceed legislative requirements and are incorporated in strategic infrastructure planning	**B**
Council stormwater quality service levels agreed to meet legislative requirements	**C**
Council stormwater quality service levels not defined	**D**
Local planning instruments and guidance	

Comprehensive water quality improvement measures are effectively integrated in local government's planning scheme exceeding *Sustainable Planning Act 2009* (and successive Queensland planning legislation) expectations and requirements, including:
• WSUD principles, objectives and measures beyond State Planning Policy (SPP) water quality requirements;
• Water quality objectives to protect and enhance environmental values (EPP Water);
• Direction to incorporate appropriate measures and actions from local catchment plans, USQMPs, TWCMP, WQIPs, HWMPs or similar, in development design;
• Mandatory development approval requirements to utilise best practice to prepare and submit for approval prior to any site works commencing;
  o An erosion prevention and sediment movement control (ESC) plan;
  o A site-based stormwater management plan (SBSMP).
	A

Water quality improvement measures effectively integrated in local government's planning scheme, as per the *Sustainable Planning Act 2009* (and successive Queensland planning legislation), including:	**B**

Water Quality Improvement Activity	Class

• WSUD principles and measures including for State interest – water quality as per the SPP;
• Water quality objectives to protect environmental values (EPP Water);
• Acknowledgement of the need to consider and incorporate appropriate measures and actions from local catchment plans, USQMPs, TWCMP, WQIPs, HWMPs or similar, in the development design;
• As a mandatory development approval condition, requirements to utilise best practice to prepare and submit for approval prior to any site works commencing;
  ○ An erosion prevention and sediment movement control (ESC) plan;
  ○ A site-based stormwater management plan (SBSMP).	

State interests - water quality incorporated in local government's planning scheme, as per the Sustainable Planning Act 2009 (and successive Queensland planning legislation), including: • Stormwater quality treatment measures, as required by the SPP, to protect the water quality State interest; • Acknowledgement of the desirability to consider appropriate measures and actions from local catchment plans, USQMPs, TWCMP, WQIPs, HWMPs or similar, in the development design; • Requirement to prepare a site stormwater quality management plan (SQMP) as per SPP acceptable outcomes; • An erosion and sediment control (ESC) plan is prepared as per SPP acceptable outcomes.	C
Local government's planning scheme defers to the SPP with regard to State interest – water quality, as per the *Sustainable Planning Act 2009* (and successive Queensland planning legislation)	D
Planning Scheme Policies (PSP) e.g. Waterways and Wetlands, and associated guidance encourages development to exceed State Planning Policy (SPP) and other legislative requirements through the use of innovative design that integrates stormwater quality management and WSUD measures in multi-function open space areas to achieve net water quality improvement and enhance local amenity	A
PSPs e.g. Waterways and Wetlands, and associated guidance encourages development to exceed SPP and other legislative requirements to achieve water quality improvement	B
PSPs e.g. Waterways and Wetlands, and associated guidance enables development to meet SPP and other legislative requirements for water quality	C
No PSP or specific guidance associated with water quality improvement	D
Stormwater management and erosion and sediment control (ESC) policy and/or planning scheme policy (PSP) supports the exceedance of State Planning Policy (SPP) requirements and promotes best practice including through IECA and locally specific guidance	A
Stormwater management and/or ESC PSP meets State Planning Policy (SPP) requirements and reflects or references best practice such as IECA guidelines to improve performance outcomes	B
Stormwater management and/or ESC PSP reflects State Planning Policy (SPP) requirements	C
No Stormwater management and/or ESC PSP	D
Council has erosion risk maps for the whole of its local government area (LGA) at a 1:10,000 scale or better and Council requires submitted ESC plans to assess erosion risk as per IECA	A
Council has erosion risk maps for most of its local government area (LGA) at a 1:100,000 scale or better and Council requires submitted ESC plans to assess erosion risk as per IECA	B
Council has erosion soil and geological maps for the whole of its local government area (LGA) to assist with assessment of erosion risk. Council requires submitted ESC plans to assess erosion risk	C
Assessment of erosion risk is not a requirement of development applications	D
Stormwater management and ESC guidelines associated with planning scheme policy (PSP), development manuals or other Council prepared water quality improvement guidance associated with development suits local climatic conditions and goes beyond best practice to exceed development approval water quality targets and outcomes	A
Stormwater management and ESC guidelines suit local climatic conditions and go beyond best practice to meet or exceed water quality objectives	B
Stormwater management and ESC guidelines suit regional climatic conditions to meet or exceed water quality objectives	C
There are no Local government stormwater management and/or ESC guidelines	D
Partnerships and planning	
Functional and effective partnerships established across the Great Barrier Reef catchment, NRM region, LGA and with neighbouring Councils to promote and achieve urban water quality improvement outcomes at local and regional levels	A
Functional partnerships established across the LGA and with neighbouring Councils to promote and achieve urban water quality improvement outcomes	B
Partnerships established across the LGA to promote urban water quality improvement	C
Urban water quality improvement is randomly promoted	D
Cultural values of waters and waterways are identified in partnership with Indigenous Traditional Owners and incorporated in planning and development assessment processes to complement and reinforce water quality improvement activities and measures	A
Cultural values of waters and waterways are identified in partnership with Indigenous Traditional Owners and incorporated in planning processes to complement and reinforce water quality improvement activities	B

Water Quality Improvement Activity	Class
Cultural values of waters and waterways are identified and incorporated in planning processes to complement and reinforce water quality improvements activities	**C**
Cultural values of waters and waterways are not included in planning processes	**D**
Implementation (*includes communications, community involvement, education, training*)	
Water sensitive urban design (WSUD)	
Water sensitive urban design (WSUD) principles and measures are incorporated in all new development to: • Exceed locally specific design objectives for treatment effectiveness as defined in the single SPP • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to normal background levels from undisturbed areas • Mimic natural flows through detention and release of water over time to reflect the hydrograph of undisturbed areas i.e. effectively achieves 0% directly connected impervious surfaces to stormwater systems	**A**
Water sensitive urban design (WSUD) principles and measures are incorporated in all new development to: • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to exceed regulatory requirements (SPP); • Approach natural flows through detention and release of water over time to resemble the hydrograph of undisturbed areas i.e. effectively achieves <10% directly connected impervious surfaces to stormwater systems	**B**
Water sensitive urban design (WSUD) principles and measures are incorporated in the majority of new development to: • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to meet regulatory requirements (SPP); • Reduce peak discharge from directly connected impervious surfaces to stormwater systems	**C**
Water sensitive urban design (WSUD) principles and measures are seldom incorporated in new development	**D**
Water Sensitive Urban Design stormwater quality measures contribute to the exceedance of water quality objectives (WQOs) for local and catchment receiving waters, as per Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water) or other WQOs adopted in lieu of EPP Water gazettal	**A**
WSUD stormwater quality measures contribute to achieving water quality objectives (WQOs) for local and catchment receiving waters, as per Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water) or other WQOs adopted in lieu of EPP Water gazettal	**B**
WSUD stormwater quality measures achieve water quality objectives (WQOs) for local receiving waters	**C**
There are insufficient WSUD stormwater quality measures to influence achievement of water quality objectives (WQOs) for local or catchment receiving waters	**D**
All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained and enhanced	**A**
All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained	**B**
The majority of water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to maintain a reasonable level of treatment efficiency	**C**
Some water quality improvement devices are maintained during the life cycle of the asset with variable levels of treatment efficiency	**D**
Site Based Stormwater Management (SBSM)	
Site Based Stormwater Management Plans (SBSMP) prepared, approved (by Council or the administering authority as part of the development application and assessment process) and implemented for all new, infill and retrofit development to surpass the single SPP construction stage stormwater management design objectives, and any additional locally specific stormwater quality and ecosystem health targets and outcomes	**A**
Site Based Stormwater Management Plans (SBSMP) prepared, approved and implemented for all new, infill and retrofit development to meet the single SPP construction stage stormwater management design objectives and any additional locally specific stormwater quality and ecosystem health targets	**B**
Site Based Stormwater Management Plans (SBSMP) prepared to meet the development approval requirements defined by the single SPP for construction stage stormwater management	**C**
Site Based Stormwater Management Plans (SBSMP) prepared to meet development approval requirements only after a Request for Further Information (RFI) is issued by Council	**D**
Erosion and sediment control (ESC)	
Above best practice erosion prevention measures are incorporated in all new, infill and retrofit development with regulatory requirements exceeded making sediment movement control measures redundant	**A**
Best practice erosion prevention and sediment control (ESC) measures are incorporated in all new, infill and retrofit development	**B**
Convention erosion and sediment control (ESC) measures are incorporated in all new, infill and retrofit development as a response to development conditions	**C**
Convention erosion and sediment control (ESC) measures are incorporated in all new, infill and retrofit development as a response to development conditions	**D**
Council only accepts ESC plans from suitably qualified professionals with CPESC qualifications [Certified Practitioner ESC?]	**A**

Water Quality Improvement Activity	Class
Council only accepts ESC plans from suitably qualified professionals as defined by Council Guidelines e.g. completed an accredited ESC course	B
Council has no requirements for ESC plan writers to be qualified	C
Council has no requirements for ESC plan writers to be qualified	D
Council staff (or contractors) assessing, approving and conditioning ESC Plans are CPESC qualified	A
Council staff (or contractors) assessing, approving and conditioning ESC Plans have a degree in Engineering, Environmental Science or other relevant discipline, and have completed specific ESC training	B
Council staff (or contractors) assessing, approving and conditioning ESC Plans have a degree in Engineering, Environmental Science or other relevant discipline	C
Council staff (or contractors) assessing, approving and conditioning ESC Plans are unqualified	D
Erosion and Sediment Control Plans (ESCP) are prepared by development applicants and approved by Council (or the administering authority as part of the development application and assessment process) for all new, infill and retrofit development incorporating innovative solutions and/or best practice to exceed regulatory requirements and water quality improvement outcomes	A
ESCPs are prepared by development applicants and approved by Council for all new, infill and retrofit development to meet and/or exceed regulatory requirements	B
ESCPs are prepared by development applicants and approved by Council for all new, infill and retrofit development to meet regulatory requirements	C
ESCPs are prepared for new development only in response to a Request for Further Information (RFI)	D
Development approval (DA) erosion and sediment control (ESC) conditions are appropriate for each site and supported by best practice guidelines (e.g. IECA, 2008) to address water quality issues while being practicable, measurable and consistent for all developments. Conditions go above best practice guidelines on high risk sites to achieve stormwater management objectives e.g. stop works during wet season and/or regulate area exposed at one time [International Erosion Control Association?]	A
DA ESC conditions are consistent with, and supported by best practice guidelines (IECA, 2008). Conditions are practicable, measurable, and consistent for all developments.	B
DA ESC conditions are consistent with SPP but do not go beyond this nor do they incorporate IECA recommendations	C
DA ESC conditions are not consistent with SPP, are not consistently applied for all developments, are rarely applied to ESC plan approvals and are not easily measurable	D
Council routinely and frequently inspects construction / development sites to assess legislative compliance, and follows-up on complaints. Council strategically use enforcement tools such as on-the-spot fines, stop work notices and prosecutions for clear breaches of ESC development conditions or regulations. Council has a track record of successfully enforcing ESC conditions and regulations, as well as procedures, systems and cultures that support successful enforcement action	A
Council routinely and frequently inspects construction / development sites to assess legislative compliance, and follows-up on complaints. Council strategically use enforcement tools such as on-the-spot fines, stop work notices and prosecutions for clear breaches of ESC development conditions or regulations	B
Council undertakes basic inspections of development sites, however rarely uses enforcement tools to address clear breaches of ESC development conditions or regulations	C
Council does not undertake investigations to monitor development compliance and does not utilise enforcement tools	D
ESC measures are voluntarily monitored/assessed/audited by developers at the appropriate stages of the development cycle using accredited third party assessors and/or in collaboration with Council with comprehensive reports provided to Council soon after each assessment	A
ESC measures are regularly monitored/assessed/audited by Council and/or third party audited by developers with reports provided to Council in a reasonable timeframe	B
ESC measures are monitored/assessed/audited by Council and/or developers on a needs basis to meet regulatory requirements. Reports are provided to Council on request	C
ESC measures are only monitored, assessed and reported on by developers following a formal request by Council	D
All developments comply with approved ESC plans, use best practice standards and voluntarily install additional erosion prevention and sediment movement control measures where needed	A
The majority of developments (>80%) voluntarily comply with approved ESC plans	B
Some developments (<50%) voluntarily comply with approved ESC plans	C
Few developments (<25%) voluntarily comply with approved ESC plans	D
Communications, community involvement, education and training	
Urban stormwater management knowledge and information requirements of major sector groups are identified, prioritised and guidance material prepared and available for all needs. Material is continually updated to reflect advances in science and industry knowledge, management practices and principles	A

Water Quality Improvement Activity	Class
Urban stormwater management knowledge and information requirements of major sector groups are identified, prioritised and guidance material prepared and available for the high and medium priority needs	B
Urban stormwater management knowledge and information requirements are identified and prioritised for major sector groups	C
Urban stormwater management knowledge and information requirements for major sector groups are unknown	D
A comprehensive set of WSUD guidance 'tools' have been developed, tested and proven to suit local conditions and assist Council and the development and construction industry to exceed regulatory requirements and WSUD performance targets and outcomes for water quality and flow	A
WSUD guidance tools have been developed to suit local conditions and assist Council and the development and construction industry to achieve and/or exceed WSUD performance outcomes and regulatory requirements for water quality and flow	B
WSUD guidance tools have been adapted/adopted to assist Council and the development and construction industry to achieve regulatory water quality requirements	C
WSUD guidance tools have been adopted in an attempt to meet regulatory water quality requirements	D
Best practice approaches identified and comprehensive guidelines prepared and available to Council staff, the development industry and community for all aspects of stormwater quality management (e.g. preparing ESC plans, assessing ESC plans and implementing ESC for development sites)	A
Best practice approaches identified and guidelines prepared and available to Council staff, the development industry and community for most aspects of stormwater quality management	B
Best practice approaches identified and guidelines prepared and available to Council staff, the development industry and community for priority topics associated with stormwater quality management	C
Inadequate guidance material about stormwater quality management available	D
Council staff are comprehensively trained in ESC and stormwater management and are capable of conducting training and mentoring public and private sector stormwater management practitioners	A
Council staff are comprehensively trained in ESC and stormwater management	B
Council staff are adequately trained in ESC and stormwater management	C
Council staff are not trained in ESC and stormwater management	D
Community and industry involvement in water quality improvement is supported through innovative and relevant community based education and involvement (CBEI) programs resulting in behaviour change and increased capacity to implement water quality improvement actions and measures Note: Examples may include: • Demonstration sites; • Locally relevant training and guidance material; • Behaviour change strategies for uptake of best practice e.g. thematic interpretation.	A
Community and industry involvement in water quality improvement is supported through innovative and relevant community based education and involvement (CBEI) programs resulting in increased capacity to implement water quality improvement actions and measures	B
Community and industry involvement in water quality improvement is supported through community based education and involvement (CBEI) programs with some increase in capacity to implement water quality improvement actions and measures	C
Community and industry involvement in water quality improvement is limited due to lack of support	D
Monitoring and Evaluation	
A world class integrated monitoring, modelling and evaluation program designed, collaboratively resourced and implemented in an adaptive planning and management framework is effectively supporting water quality improvement	A
A comprehensive monitoring, modelling and evaluation program designed and implemented in an adaptive planning and management framework to support water quality improvement	B
A monitoring and evaluation program designed and implemented to meet regulatory requirements	C
No monitoring program in place to support water quality improvement	D
Water quality improvement actions are regularly monitored and assessed as part of an adaptive planning and management approach that supports active management practice improvement in 'real time'	A
Water quality improvement actions are monitored and assessed as part of an adaptive planning and management approach that supports management practice improvement over time	B
Water quality improvement actions are monitored and assessed irregularly or infrequently	C
Water quality improvement action performance is not monitored and/or assessed	D
Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken as part of a comprehensive water quality improvement monitoring, modelling and evaluation program to ensure treatment effectiveness is maintained and enhanced over the lifecycle of the asset	A
Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken to ensure treatment effectiveness is maintained over the lifecycle of the asset	B

Water Quality Improvement Activity	Class
Monitoring of stormwater management treatment measures is undertaken occasionally to determine the level of treatment effectiveness	**C**
Stormwater management assets/treatment measures are not monitored	**D**
Comprehensive stormwater management records are kept including for; water quality monitoring, stormwater management asset/measure effectiveness, stormwater management asset maintenance regimes and costs, stormwater management asset establishment and construction costs and non-compliance issues and remedies. Records are made readily available for inclusion in local and regional performance reporting	**A**
Stormwater management records are kept including for; water quality monitoring, and stormwater management asset maintenance regimes and costs. Records are made available for inclusion in local and regional reporting	**B**
Stormwater management records are kept including for; water quality monitoring, and stormwater management asset maintenance regimes. Records are made available if specifically requested	**C**
No stormwater management records are kept	**D**
Industry voluntarily provides data to allow reporting to community on stormwater management performance achievements as part of a world class monitoring, modelling and evaluation program that is effectively promoting and achieving water quality improvement	**A**
Industry voluntarily provides data to allow reporting to community on performance achievements and any non-compliances	**B**
Industry provides stormwater management data at the request of Council to allow anonymous reporting to community on industry performance achievements and non-compliances	**C**
Industry does not provide stormwater management data for performance reporting	**D**
An integrated report card developed to effectively communicate environmental, social and economic outcomes and delivered as part of a world class monitoring, modelling and evaluation program promoting and achieving water quality improvement	**A**
An integrated report card developed and delivered to communicate environmental, social and economic outcomes of water quality improvement efforts	**B**
A report card developed to communicate environmental outcomes of water quality improvement efforts	**C**
No effective water quality improvement outcome reporting	**D**
Erosion and sediment control (ESC)	
Council undertakes water quality monitoring during/after rainfall events downstream of large developments and high erosion risk sites with financial contribution from the developer and/or development industry through a regional water quality monitoring program. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**A**
Council requires the developer undertake water quality monitoring during/after rainfall events downstream of their development if it is large scale and/or a high erosion risk site. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**B**
Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**C**
Council does not undertake any water quality monitoring and there are no requirements for developers to undertake monitoring	**D**
Site Based Stormwater Management (SBSM)	
Site Based Stormwater Management Plan (SBSMP) implementation is voluntarily monitored/assessed/audited by developers at the appropriate stages of the development cycle using accredited third party assessors and/or in collaboration with Council with comprehensive reports provided to Council soon after each assessment	**A**
SBSMP implementation is regularly monitored/assessed/audited by Council and/or third party audited by developers with reports provided to Council in a reasonable timeframe	**B**
SBSMP implementation is monitored/assessed/audited by Council and/or developers on a needs basis to meet regulatory requirements. Reports are provided to Council on request	**C**
SBSMP implementation is only monitored, assessed and reported on by developers following a formal request by Council	**D**

Note: NWQMS is the National Water Quality Management Strategy.

Table 2. Draft Private Sector Development ABCD Classification.

Water Quality Improvement Activity	Class
Policy, Planning and Partnerships	
* Stormwater infrastructure is designed using best practice integrated stormwater management principles and measures i.e. addresses quality, quantity and hydrology, to mimic conditions associated with stormwater run-off from natural areas	**A**
Stormwater infrastructure is designed to reflect best practice stormwater management i.e. integrated quantity (flood mitigation) and quality, using a catchment–based total water cycle management approach	**B**
Stormwater infrastructure is designed to meet regulatory requirements including use of best practice stormwater management including encouraging use of rain water tanks as part of the urban water quality treatment train	**C**
Stormwater infrastructure is designed to meet regulatory requirements	**D**
Industry voluntarily engages Council in discussions about asset handover and ongoing maintenance requirements early in the development cycle enabling functional and effective planning for rectification works, if required, and transition to Council maintenance of stormwater management assets	**A**
Industry engages in discussions with Council about maintenance and asset handover during the development cycle enabling functional transition planning for ongoing Council maintenance of stormwater management assets	**B**
Industry engages in Council instigated discussions over maintenance and asset handover during the development cycle to meet regulatory requirements for handover of stormwater management assets to Council	**C**
Industry engages in discussions with Council over maintenance and handover of stormwater management assets asset handover during the development cycle to meet regulatory requirements for	**D**
An adaptive planning and management approach is utilised in all master-planned and/or staged developments to ensure continuous improvement in integrated stormwater quality planning, design and management practices	**A**
An adaptive planning and management approach is utilised in all master-planned and/or staged developments to enable continuous improvement in stormwater management practices over time	**B**
Master-planned and staged developments use traditional stormwater management practices with minor incremental improvement over time	**C**
Master-planned and staged developments use outdated stormwater management practices for flood mitigation only	**D**
Implementation (*includes communications, community involvement, education, training*)	
Water sensitive urban design (WSUD)	
* Water sensitive urban design (WSUD) principles and measures are incorporated in all new development to: • Exceed locally specific design objectives for treatment effectiveness as defined in the single SPP • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to normal background levels from undisturbed areas • Mimic natural flows through detention and release of water over time to reflect the hydrograph of undisturbed areas i.e. effectively achieves 0% directly connected impervious surfaces to stormwater systems	**A**
WSUD principles and measures are incorporated in all new development to: • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to exceed regulatory requirements (SPP); • Approach natural flows through detention and release of water over time to resemble the hydrograph of undisturbed areas i.e. effectively achieves <10% directly connected impervious surfaces to stormwater systems	**B**
WSUD principles and measures are incorporated in the majority of new development to: • Reduce the water pollutant loads reaching receiving waters from development sites and mature urban areas to meet regulatory requirements (SPP); • Reduce peak discharge from directly connected impervious surfaces to stormwater systems	**C**
WSUD principles and measures are seldom incorporated in new development	**D**
* All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained and enhanced	**A**
All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained	**B**
The majority of water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to maintain a reasonable level of treatment efficiency	**C**
Some water quality improvement devices are maintained during the life cycle of the asset with variable levels of treatment efficiency	**D**
Site Based Stormwater Management (SBSM)	
* Site Based Stormwater Management Plans (SBSMP) prepared, approved (by Council or the administering authority as part of the development application and assessment process) and implemented for all new, infill and retrofit development to surpass the single SPP construction stage stormwater management design objectives, and any additional locally specific stormwater quality and ecosystem health targets and outcomes	**A**
SBSMP prepared, approved and implemented for all new, infill and retrofit development to meet the single SPP construction stage stormwater management design objectives and any additional locally specific stormwater quality and ecosystem health targets	**B**

Water Quality Improvement Activity	Class
SBSMP prepared to meet the development approval requirements defined by the single SPP for construction stage stormwater management	C
SBSMP prepared to meet development approval requirements only after a Request for Further Information (RFI) is issued by Council	D
*Site Based Stormwater Management Plan (SBSMP) implementation is voluntarily monitored/assessed/audited by developers at the appropriate stages of the development cycle using accredited third party assessors and/or in collaboration with Council with comprehensive reports provided to Council soon after each assessment	A
SBSMP implementation is regularly monitored/assessed/audited by Council and/or third party audited by developers with reports provided to Council in a reasonable timeframe	B
SBSMP implementation is monitored/assessed/audited by Council and/or developers on a needs basis to meet regulatory requirements. Reports are provided to Council on request	C
SBSMP implementation is only monitored, assessed and reported on by developers following a formal request by Council	D
Non-compliance with legislative requirements and development approval conditions does not occur	A
Non-compliance with legislative requirements and development approval conditions is infrequent and then only minor i.e. contained on site	B
Non-compliance with legislative requirements and development approval conditions occurs but is able to be remediated without significant off-site environmental harm being caused	C
Non-compliance with legislative requirements and development approval conditions occurs but is able to be remediated without significant environmental harm being caused	D
Site Based Stormwater Management Plan (SBSMP) operational components including maintenance schedules are adjusted as necessary to exceed regulatory requirements and water quality improvement objectives	A
SBSMP maintenance schedules are adjusted as necessary to ensure all regulatory requirements are achieved	B
SBSMP maintenance schedules are adhered to	C
SBSMP maintenance schedules are seldom adhered to	D
Site Based Stormwater Management Plan (SBSMP) incorporates an adaptive management strategy and is amended responsively to exceed expectations and management objectives	A
SBSMP incorporates an adaptive management strategy and is amended as required to meet and/or exceed regulatory requirements	B
SBSMP is amended reactively to meet regulatory requirements	C
SBSMP is only amended in response to a show cause notice, reprimand or official request	D
Site Based Stormwater Management Plan (SBSMP) includes a comprehensive water quality monitoring program i.e. stormwater flow and base flow sampled prior to, during and after construction activities, designed to measure the efficacy of the plan and identify improvement options	A
An approved water quality monitoring program (stormwater flow and base flow) is undertaken prior to, during and after construction activities to measure plan performance	B
A basic water quality monitoring program is undertaken to measure baseline and post construction water quality	C
Water quality monitoring is undertaken if requested or in response to a breach of conditions	D
Erosion and sediment control (ESC)	
Installation of erosion and sediment control (ESC) measures precedes land development and construction works and exceeds approved Erosion and Sediment Control Plan (ESCP) measures	A
Installation of approved ESCP measures precedes land development and construction works	B
Installation of approved ESCP measures occurs during land development and construction works or following condition breaches	C
ESCP measures are installed only as result of compliance assessment	D
Erosion and Sediment Control Plan (ESCP) incorporates an adaptive management strategy and is amended responsively to exceed expectations and management objectives	A
ESCP incorporates an adaptive management strategy and is amended as required to meet and/or exceed regulatory requirements	B
ESCP is amended reactively to meet regulatory requirements	C
ESCP is only amended in response to a show cause notice, reprimand or official request	D
Vegetation clearing and/or soil exposure for land development or construction does not occur during the wet season (November to May)	A
Vegetation clearing and/or soil exposure for land development does not occur during the wet season (November to May). Clearing/disturbance for construction (December to March) is limited to the area required for construction purposes	B
Vegetation clearing and/or soil exposure for land development and/or construction is limited during the wet season (December to March)	C
Vegetation clearing and/or soil exposure for land development and/or construction is undertaken at any time of the year and often across the entire site at the start of the development	D

Water Quality Improvement Activity	Class
***** Erosion and sediment control (ESC) measures are voluntarily monitored/assessed/audited by developers at the appropriate stages of the development cycle using accredited third party assessors and/or in collaboration with Council with comprehensive reports provided to Council soon after each assessment	**A**
ESC measures are regularly monitored/assessed/audited by Council and/or third party audited by developers with reports provided to Council in a reasonable timeframe	**B**
ESC measures are monitored/assessed/audited by Council and/or developers on a needs basis to meet regulatory requirements. Reports are provided to Council on request	**C**
ESC measures are only monitored, assessed and reported on by developers following a formal request by Council	**D**
Communications, community involvement, education and training	
Industry leads in the development of comprehensive training programs and provides support to ensure its practitioners are fully trained in current best practice for all aspects of site stormwater quality management and improvement to enable exceedance of water quality regulatory requirements. May include provision and maintenance of best practice demonstration sites	**A**
Industry ensures its practitioners are trained in current best practice for all aspects of site stormwater quality management and especially erosion prevention measures and site rehabilitation/revegetation activities	**B**
Industry encourage its practitioners to undertake self-development in site stormwater quality management best practice	**C**
Industry is indifferent with regard to stormwater management practitioners capacity	**D**
Monitoring and Evaluation	
Erosion and sediment control (ESC)	
***** Council undertakes water quality monitoring during/after rainfall events downstream of large developments and high erosion risk sites with financial contribution from the developer and/or development industry through a regional water quality monitoring program. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**A**
Council requires the developer undertake water quality monitoring during/after rainfall events downstream of their development if it is large scale and/or a high erosion risk site. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**B**
Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**C**
Council does not undertake any water quality monitoring and there are no requirements for developers to undertake monitoring	**D**
***** Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken as part of a comprehensive water quality improvement monitoring, modelling and evaluation program to ensure treatment effectiveness is maintained and enhanced over the lifecycle of the asset	**A**
Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken to ensure treatment effectiveness is maintained over the lifecycle of the asset	**B**
Monitoring of stormwater management treatment measures is undertaken occasionally to determine the level of treatment effectiveness	**C**
Stormwater management assets/treatment measures are not monitored	**D**
***** Comprehensive stormwater management records are kept including for; water quality monitoring, stormwater management asset/measure effectiveness, stormwater management asset maintenance regimes and costs, stormwater management asset establishment and construction costs and non-compliance issues and remedies. Records are made readily available for inclusion in local and regional performance reporting	**A**
Stormwater management records are kept including for; water quality monitoring, and stormwater management asset maintenance regimes and costs. Records are made available for inclusion in local and regional reporting	**B**
Stormwater management records are kept including for; water quality monitoring, and stormwater management asset maintenance regimes. Records are made available if specifically requested	**C**
No stormwater management records are kept	**D**
***** Industry voluntarily provides data to allow reporting to community on stormwater management performance achievements as part of a world class monitoring, modelling and evaluation program that is effectively promoting and achieving water quality improvement	**A**
Industry voluntarily provides data to allow reporting to community on performance achievements and any non-compliances	**B**
Industry provides stormwater management data at the request of Council to allow anonymous reporting to community on industry performance achievements and non-compliances	**C**
Industry does not provide stormwater management data for performance reporting	**D**

Note: ***** Included in local government area regulator/manager ABCD and/or public sector development ABCD.

Table 3. Draft Public Sector Development/Construction ABCD Classification.

Water Quality Improvement Activity	Class
Policy, Planning and Partnerships	
Stormwater infrastructure is designed using best practice integrated stormwater management principles and measures i.e. addresses quality, quantity and hydrology, to mimic conditions associated with stormwater run-off from natural areas	**A**
Stormwater infrastructure is designed to reflect best practice stormwater management i.e. integrated quantity (flood mitigation) and quality, using a catchment–based total water cycle management approach	**B**
Stormwater infrastructure is designed to meet regulatory requirements including use of best practice stormwater management including encouraging use of rain water tanks as part of the urban water quality treatment train	**C**
Stormwater infrastructure is designed to meet regulatory requirements	**D**
WSUD principles and best practice stormwater management measures are included in the design of all Council managed and implemented community infrastructure projects and all Council construction/development activities exceed regulatory requirements	**A**
WSUD principles and best practice stormwater management measures are included in the design of all Council managed and implemented community infrastructure projects and all Council construction/development activities meet regulatory requirements	**B**
Best practice stormwater management measures are included in the design of all Council managed and implemented construction/development activities	**C**
Stormwater management measures are necessarily included in the design of Council managed and implemented construction/development activities	**D**
Implementation (*includes communications, community involvement, education, training*)	
Water sensitive urban design (WSUD)	
Water Sensitive Urban Design (WSUD) stormwater quality measures contribute to the exceedance of water quality objectives (WQOs) for local and catchment receiving waters, as per Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water) or other WQOs adopted in lieu of EPP Water gazettal	**A**
WSUD stormwater quality measures contribute to achieving water quality objectives (WQOs) for local and catchment receiving waters, as per Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water) or other WQOs adopted in lieu of EPP Water gazettal	**B**
WSUD stormwater quality measures achieve water quality objectives (WQOs) for local receiving waters	**C**
There are insufficient WSUD stormwater quality measures to influence achievement of water quality objectives (WQOs) for local or catchment receiving waters	**D**
All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained and enhanced	**A**
All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained	**B**
The majority of water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to maintain a reasonable level of treatment efficiency	**C**
Some water quality improvement devices are maintained during the life cycle of the asset with variable levels of treatment efficiency	**D**
Site Based Stormwater Management (SBSM)	
Site Based Stormwater Management Plans (SBSMP) prepared by Council and implemented for all new, infill and retrofit development to surpass the single SPP construction stage stormwater management design objectives, and any additional locally specific stormwater quality and ecosystem health targets and outcomes	**A**
SBSMP prepared and implemented for all new, infill and retrofit development to meet the single SPP construction stage stormwater management design objectives and any additional locally specific stormwater quality and ecosystem health targets	**B**
SBSMP prepared to meet the development approval requirements defined by the single SPP for construction stage stormwater management	**C**
SBSMP not prepared	**D**
***Site Based Stormwater Management Plan (SBSMP) implementation is comprehensively monitored/assessed/audited at the appropriate stages of the development cycle using accredited third party assessors	**A**
SBSMP implementation is regularly monitored/assessed/audited by Council and/or third party audited	**B**
SBSMP implementation is monitored/assessed/audited by Council on a needs basis to meet regulatory requirements	**C**
SBSMP implementation is not monitored or assessed	**D**
Non-compliance with legislative requirements and development approval conditions does not occur	**A**
Non-compliance with legislative requirements and development approval conditions is infrequent and then only minor i.e. contained on site	**B**
Non-compliance with legislative requirements and development approval conditions occurs but is able to be remediated without significant off-site environmental harm being caused	**C**

Water Quality Improvement Activity	Class
Non-compliance with legislative requirements and development approval conditions occurs but is able to be remediated without significant environmental harm being caused	D
Site Based Stormwater Management Plan (SBSMP) operational components including maintenance schedules are adjusted as necessary to exceed regulatory requirements and water quality improvement objectives	A
SBSMP maintenance schedules are adjusted as necessary to ensure all regulatory requirements are achieved	B
SBSMP maintenance schedules are adhered to	C
SBSMP maintenance schedules are seldom adhered to	D
Site Based Stormwater Management Plan (SBSMP) incorporates an adaptive management strategy and is amended responsively to exceed expectations and management objectives	A
SBSMP incorporates an adaptive management strategy and is amended as required to meet and/or exceed regulatory requirements	B
SBSMP is amended reactively to meet regulatory requirements	C
SBSMP is only amended in response to a show cause notice, reprimand or official request	D
Site Based Stormwater Management Plan (SBSMP) includes a comprehensive water quality monitoring program i.e. stormwater flow and base flow sampled prior to, during and after construction activities, designed to measure the efficacy of the plan and identify improvement options	A
An approved water quality monitoring program (stormwater flow and base flow) is undertaken prior to, during and after construction activities to measure plan performance	B
A basic water quality monitoring program is undertaken to measure baseline and post construction water quality	C
Water quality monitoring is undertaken if requested or in response to a breach of conditions	D
Erosion and sediment control (ESC)	
Installation of erosion and sediment control (ESC) measures precedes land development and construction works and exceeds approved Erosion and Sediment Control Plan (ESCP) measures	A
Installation of approved ESCP measures precedes land development and construction works	B
Installation of approved ESCP measures occurs during land development and construction works or following condition breaches	C
ESCP measures are installed only as result of compliance assessment	D
Erosion and Sediment Control Plan (ESCP) incorporates an adaptive management strategy and is amended responsively to exceed expectations and management objectives	A
ESCP incorporates an adaptive management strategy and is amended as required to meet and/or exceed regulatory requirements	B
ESCP is amended reactively to meet regulatory requirements	C
ESCP is only amended in response to a show cause notice, reprimand or official request	D
Vegetation clearing and/or soil exposure for land development or construction does not occur during the wet season (November to May)	A
Vegetation clearing and/or soil exposure for land development does not occur during the wet season (November to May). Clearing/disturbance for construction (December to March) is limited to the area required for construction purposes	B
Vegetation clearing and/or soil exposure for land development and/or construction is limited during the wet season (December to March)	C
Vegetation clearing and/or soil exposure for land development and/or construction is undertaken at any time of the year and often across the entire site at the start of the development	D
***** ESC measures are voluntarily monitored/assessed/audited by developers at the appropriate stages of the development cycle using accredited third party assessors and/or in collaboration with Council with comprehensive reports provided to Council soon after each assessment	A
ESC measures are regularly monitored/assessed/audited by Council and/or third party audited by developers with reports provided to Council in a reasonable timeframe	B
ESC measures are monitored/assessed/audited by Council and/or developers on a needs basis to meet regulatory requirements. Reports are provided to Council on request	C
ESC measures are only monitored, assessed and reported on by developers following a formal request by Council	D
Council policies, strategies and procedures are in place to ensure that ESC standards on building, construction and maintenance works conducted by local government (or state government) are at least best practice. Public sector works set a positive example for the private development and construction industry	A
Council policy and procedures are in place to ensure that ESC standards on building, construction and maintenance works conducted by local government (or state government) are best practice and provide an example of the standards required to meet and/or exceed regulatory requirements under the SPP	B
Council procedures are in place to ensure that ESC standards on building, construction and maintenance works conducted by local government (or state government) are best practice and provide an example of the minimum standard required to meet regulatory requirements under the SPP	C
Council procedures are inadequate to ensure that ESC measures on building, construction and maintenance works conducted by local government meet regulatory	D

Water Quality Improvement Activity	Class
Council prepares appropriately comprehensive site rehabilitation plans for all sites and ensures all works undertaken by or on behalf of Council are adequately revegetated/stabilised as soon as practicable after works are completed and integrated with any adjacent open space and/or rehabilitation/revegetation projects/works	**A**
Council prepares site rehabilitation plans for high risk sites and ensures all works undertaken by or on behalf of Council are adequately revegetated/stabilised as soon as practicable after works are completed	**B**
No site rehabilitation plans prepared and only high risk sites are adequately revegetated/ stabilised after works are completed	**C**
No site rehabilitation plans prepared and inadequate rehabilitation works if any	**D**
Communications, community involvement, education and training	
***** Best practice approaches identified and comprehensive guidelines prepared and available to Council staff for all aspects of stormwater quality management (e.g. preparing ESC plans, assessing ESC plans and implementing ESC for development sites)	**A**
Best practice approaches identified and guidelines prepared and available to Council staff for most aspects of stormwater quality management	**B**
Best practice approaches identified and guidelines prepared and available to Council staff for priority topics associated with stormwater quality management	**C**
Inadequate guidance material about stormwater quality management available to Council staff	**D**
Monitoring and Evaluation	
Council undertakes water quality monitoring during/after rainfall events downstream of large developments and high erosion risk sites with financial contribution from the developer and/or development industry through a regional water quality monitoring program. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**A**
Council requires the developer undertake water quality monitoring during/after rainfall events downstream of their development if it is large scale and/or a high erosion risk site. Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**B**
Council requires all development sites with sediment basins to monitor discharge water and report results to Council	**C**
Council does not undertake any water quality monitoring and there are no requirements for developers to undertake monitoring	**D**

Note: ***** Included in regulator/manager ABCD and/or private sector development ABCD.

Table 4. Draft Mature Urban ABCD Management Practice Classification.

Water Quality Improvement Activity	Class
Policy, Planning and Partnerships	
Policy and strategic planning	
***** Council actively supports catchment-based total water cycle management as a pathway for water quality and ecosystem health protection and improvement and this is reflected in its policies, strategies and initiatives which are resourced and implemented in partnership with all relevant stakeholders to accelerate water quality improvement outcomes	**A**
Council acknowledges the need for a catchment-based total water cycle management approach to water quality and ecosystem health improvement and its policy supports the achievement of water quality improvement over time with available resources	**B**
Council policy acknowledges the need for total water cycle management and ecosystem health protection in partnership with other stakeholders	**C**
Council acknowledges the need for other stakeholders to improve water quality and ecosystem health	**D**
***** A strategic catchment management plan (as per the NWQMS), water quality improvement plan (WQIP) (as per Reef Plan 2003), total water cycle management plan (TWCMP) (as per the previous EPP Water including USQMP), healthy waters management plan (HWMP) (as per current EPP Water) or similar strategy plan prepared in conjunction with relevant stakeholders linking; flood mitigation, water sensitive urban design (WSUD), stormwater management (including erosion prevention), waterway management, potable water supply, wastewater treatment and water conservation with the protection of natural assets, environmental infrastructure, hydrological and ecological functions and ecosystem services. Plans incorporate an adaptive planning and management approach ensuring they are regularly reviewed and updated to reflect emerging best practice and locally relevant data, information and learnings	**A**
A catchment management strategy, WQIP, TWCMP, HWMP or similar strategy plan prepared in conjunction with relevant stakeholders incorporating; flood mitigation, water sensitive urban design (WSUD), stormwater management (including erosion prevention), waterway management, wastewater treatment and water conservation	**B**
A catchment management strategy, WQIP, TWCMP, HWMP or similar strategy plan prepared incorporating; flood mitigation, stormwater system management and water conservation	**C**
No catchment-based strategic water quality improvement plans prepared	**D**

Water Quality Improvement Activity	Class
* [1] An Urban Stormwater Quality Management Plan (USQMP) prepared by Council for mature urban areas, as a component of a WQIP, TWCMP, HWMP or similar, that links with and comprehensively integrates succession planning for environmental infrastructure from developing areas. Developing areas are regularly integrated with the USQMP as part of the USQMP adaptive management framework	**A**
USQMP prepared by Council for mature urban areas, as a component of a WQIP, TWCMP, HWMP or similar, and links with and/or integrates succession planning for developing areas	**B**
USQMP prepared by Council as per the EPP Water (now superseded)	**C**
No USQMP, or similar, prepared by Council	**D**
* Strategic landscape and comprehensive local scale mapping prepared for planning and decision making including for identification and prioritisation of areas for location of protection mechanisms and treatment measures for maximum water quality improvement benefits and outcomes	**A**
Strategic landscape and local scale mapping prepared for planning and decision making including for identification and prioritisation of areas for location of protection mechanisms and treatment measures for water quality improvement	**B**
Strategic landscape scale mapping prepared for planning and decision making for initial identification of areas for location of protection mechanisms and treatment measures for water quality improvement	**C**
Acknowledged need for mapping to inform planning and decision making for water quality improvement	**D**
Detailed catchment and/or sub catchment management plans are progressively prepared for all urban and peri-urban areas as the operational and on-ground component of WQIPs, TWCMPs, HWMPs, USQMPs or other strategy to support waterway management and rehabilitation efforts. Responsible bodies regularly review and update strategic plans and operational catchment and sub catchment management plans, using an adaptive planning and management approach, to ensure they reflect emerging best practice and incorporate locally relevant data, information and learnings	**A**
Detailed catchment and/or sub catchment management plans are progressively prepared over time, starting with priority urban areas, as the operational and on-ground component of WQIPs, TWCMPs, HWMPs, USQMPs or other strategy to support waterway management and rehabilitation efforts	**B**
Waterway management and rehabilitation plans are prepared over time for high priority urban areas as the operational and on-ground component of WQIPs, TWCMPs, HWMPs, USQMPs or other strategy	**C**
Waterway management and rehabilitation is relatively uncoordinated	**D**
Implementation (*includes communications, community involvement, education, training*)	
Urban stormwater quality management	
An innovative, integrated, practical and effective urban stormwater quality management program is being implemented in collaboration with industry and community and incorporates existing strategic plans, programs and projects including Urban Stormwater Quality Management Plans (USQMP), WQIPs, TWCMPs, HWMPs and their operational components	**A**
An integrated and practical urban stormwater quality management program is being implemented in collaboration with industry and community and incorporates existing strategic plans, programs and projects including USQMPs, WQIPs, TWCMPs, HWMPs and their operational components	**B**
Some operational components of existing strategic plans and the USQMP are being implemented by Council and/or in collaboration with industry and community	**C**
No realistic urban stormwater quality management program exists	**D**
Site based stormwater management plans (SBSMP), including erosion prevention and sediment movement control and WSUD principles and measures are prepared and implemented for infill development and redevelopment, regardless of development approval requirements i.e. SBSMP may not be required for blocks < 2,500m^2, exceeding the requirements of the construction phase stormwater management design objectives under the single State Planning Policy (SPP)	**A**
SBSMPs, including erosion prevention and sediment movement control and WSUD principles and measures are prepared and implemented for infill development and redevelopment, regardless of development approval requirements, achieving SPP construction phase stormwater management design objectives	**B**
SBSMPs are prepared and implemented for infill development and redevelopment in compliance with any relevant development approval conditions	**C**
Site based stormwater management plans are not required for infill development and redevelopment	**D**
Retrofit and upgrade opportunities for stormwater management and water sensitive urban design (WSUD) measures are comprehensively investigated, mapped, modelled, assessed and prioritised for urban and peri-urban areas (public and private land). Retrofit and upgrade opportunities are systematically implemented across public open space and private redevelopment sites as part of a long term, integrated urban stormwater management improvement program utilising innovative and collaborative public/private sector a community partnerships Note: the road system is considered in retrofit investigations e.g. grassed swales and bioretention pods	**A**
Retrofit and upgrade opportunities for stormwater management and water sensitive urban design (WSUD) measures are investigated, mapped, modelled and prioritised for urban areas (public and private land). Resources are actively	**B**

Water Quality Improvement Activity	Class
sought and high and medium priority opportunities are implemented across public open space and private redevelopment sites over time	
Retrofit and upgrade opportunities for stormwater management and water sensitive urban design (WSUD) measures are identified and prioritised for public urban land. High priority opportunities are implemented as resources become available	**C**
No structured stormwater management retrofit investigations or implementation	**D**
Council managed maintenance works have exemplary erosion prevention and sediment movement control measures in place ensuring stormwater runoff does not transport sediment to receiving waters above background levels of natural areas	**A**
Council managed maintenance works have more than adequate erosion prevention and sediment movement control measures in place to ensure sediment in stormwater runoff exceeds the requirements of the construction phase stormwater management design objectives and meets the intent of the post construction phase stormwater management design objectives under the single State Planning Policy (SPP)	**B**
Council managed maintenance works have adequate erosion and sediment control (ESC) measures in place to ensure sediment in stormwater runoff does not exceed the levels of the SPP construction phase stormwater management design objectives	**C**
Council managed maintenance works have inadequate ESC measures in place	**D**
Open space is designed to be multi-functional incorporating water sensitive urban design (WSUD) principles and integrated stormwater management measures that detain and treat urban stormwater runoff resulting in hydrological conditions and water quality that is characteristic of natural areas	**A**
Open space is multi-functional incorporating WSUD principles and stormwater management measures that aid in the detention and treatment of urban stormwater runoff resulting in water quality that exceeds the requirements of the post construction phase stormwater management design objectives under the single State Planning Policy (SPP)	**B**
Open space sometimes includes stormwater management measures that aid in the treatment and/or detention of urban stormwater runoff to contribute to the achievement of the water quality objectives (WQOs) in Schedule 1 of the *Environmental Protection (Water) Policy 2009*, and/or other local water quality targets	**C**
Open space is not seen to be an appropriate to locate stormwater management measures	**D**
Open space maintenance activities e.g. mowing, fertiliser and/or pesticide application and resurfacing, incorporate innovative practice resulting in sediment, nutrient, pesticide and gross pollutant concentrations in rainfall run-off normally associated with natural areas	**A**
Open space maintenance activities incorporate best practice ensuring sediment, nutrient, and gross pollutant levels in rainfall run-off reaching receiving waters are below the concentrations defined in the single State Planning Policy (SPP) post construction phase stormwater management design objectives	**B**
Open space maintenance activities may result in sediment, nutrient, pesticide and gross pollutants concentrations in rainfall run-off exceeding the water quality objectives (WQOs) in Schedule 1 of the *Environmental Protection (Water) Policy 2009*, and/or other local water quality targets	**C**
Open space maintenance activities increase sediment, nutrient, pesticide and/or gross pollutants levels in rainfall run-off	**D**
Urban waterways and wetlands have high ecological value, intact riparian vegetation and habitat capable of filtering sediment and nutrients from stormwater runoff mimicking water quality from natural areas entering receiving waters	**A**
Urban waterways and wetlands have intact riparian vegetation capable of filtering the majority of sediment and particulate nutrients and some soluble nitrogen from stormwater runoff before it reaches receiving waters	**B**
Urban waterways and wetlands have relatively intact riparian vegetation capable of filtering some sediment and particulate nutrients from stormwater runoff before it reaches receiving waters	**C**
Urban waterway and wetland riparian vegetation is in poor condition and incapable of filtering most sediment and nutrients from stormwater runoff before it reaches receiving waters	**D**
***** [1] Stormwater management systems and stormwater quality improvement measures and devices are managed and maintained over the life cycle of the assets to ensure treatment efficiencies are maintained and enhanced to meet or exceed locally specific stormwater management design objectives i.e. in terms of load reductions, contributing to the achievement or improvement of adopted water quality objectives (WQO) for receiving waters	**A**
Stormwater management systems and stormwater quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained	**B**
The majority of stormwater quality improvement devices are managed and maintained appropriately over the life cycle of the asset to maintain a reasonable level of treatment efficiency	**C**
Some water quality improvement devices are maintained during the life cycle of the asset with variable levels of treatment efficiency	**D**
Communications, community involvement, education and training	
***** [1] Community and industry involvement in total water cycle water management and water quality improvement is supported through innovative and relevant community based education and involvement (CBEI) programs resulting in behaviour change and a greatly increased capacity to implement water quality improvement actions and measures	**A**

Water Quality Improvement Activity	Class
Note: Examples may include: • Demonstration sites; • Locally relevant training and guidance material; • Best practice market based incentive options; • Behaviour change strategies for uptake of best practice e.g. thematic interpretation.	
Community and industry involvement in water quality improvement is supported through innovative and relevant community based education and involvement (CBEI) programs resulting in increased capacity to implement water quality improvement actions and measures	**B**
Community and industry involvement in water quality improvement is supported through community based education and involvement (CBEI) programs with some increase in capacity to implement water quality improvement actions and measures	**C**
Community and industry involvement in water quality improvement is limited due to lack of support	**D**
***** [1] Following the identification and prioritisation of knowledge and information requirements of major sector groups a comprehensive set of WSUD guidance 'tools' have been developed, tested and proven to suit local conditions and assist Council, the development and construction industry and other urban stormwater managers (includes community) to exceed regulatory requirements and WSUD performance targets and outcomes for water quality and flow. Material is continually updated to reflect advances in science and industry knowledge, management practices and principles	**A**
Following the identification and prioritisation of knowledge and information requirements of major sector groups WSUD guidance tools have been developed to suit local conditions for the high and medium priority needs and assist Council, the development and construction industry and other urban stormwater managers to achieve and/or exceed WSUD performance outcomes and regulatory requirements for water quality and flow	**B**
WSUD guidance tools have been adopted or adapted to assist Council, the development and construction industry and other urban stormwater managers to achieve regulatory water quality requirements	**C**
WSUD guidance tools may have been adopted in an attempt to meet regulatory water quality requirements. Urban stormwater management knowledge and information requirements for major sector groups are unknown	**D**
***** [1] Best practice approaches identified and comprehensive guidelines prepared and available to Council staff, the development/construction industry and community for all aspects of stormwater quality management	**A**
Best practice approaches identified and guidelines prepared and available to Council staff, the development industry and community for most aspects of urban stormwater quality management	**B**
Best practice approaches identified and guidelines prepared and available to Council staff, the development/construction industry and community for priority topics associated with urban stormwater quality management	**C**
Inadequate guidance material about urban stormwater quality management available	**D**
***** [1] Council staff are comprehensively trained in integrated stormwater management (quality and quantity) competencies, including erosion and sediment control (ESC), and are more than capable of conducting training and/or mentoring public and private sector stormwater management practitioners	**A**
Council staff are comprehensively trained in stormwater management competencies	**B**
Council staff are adequately trained in stormwater management competencies	**C**
Council staff are not trained in stormwater management	**D**
As a result of interaction with and active participation in CBEI and behaviour change programs there is an 80% increase in the number of residents, businesses and industries implementing best practices for water quality improvement in their homes and workplace	**A**
As a result of interaction with CBEI and behaviour change programs there is a 50% increase in the number of residents, businesses and industries implement best practices for water quality improvement in their homes and workplace	**B**
As a result of interaction with CBEI and behaviour change programs there is a 20% increase in the number of residents, businesses and industries implement best practices for water quality improvement in their homes and workplace	**C**
Little or no improvement in uptake of best practices for water quality improvement due to absence of CBEI and behaviour change programs	**D**
Monitoring and Evaluation	
***** A world class integrated monitoring, modelling and evaluation program designed, collaboratively resourced and implemented in an adaptive planning and management framework is effectively supporting and advancing water quality improvement	**A**
A comprehensive monitoring, modelling and evaluation program designed and implemented in an adaptive planning and management framework to support water quality improvement	**B**
A monitoring and evaluation program designed and implemented to meet regulatory requirements	**C**
No monitoring program in place to support water quality improvement	**D**
***** Water quality improvement actions are regularly monitored and assessed as part of an adaptive planning and management approach that supports active management practice improvement in 'real time'	**A**

Water Quality Improvement Activity	Class
Water quality improvement actions are monitored and assessed as part of an adaptive planning and management approach that supports management practice improvement over time	**B**
Water quality improvement actions are monitored and assessed irregularly or infrequently	**C**
Water quality improvement action performance is not monitored and/or assessed	**D**
***** Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken as part of a comprehensive water quality improvement monitoring, modelling and evaluation program to ensure treatment effectiveness is maintained and enhanced over the lifecycle of the asset	**A**
Regular monitoring of the effectiveness of stormwater management assets/treatment measures is undertaken to ensure treatment effectiveness is maintained over the lifecycle of the asset	**B**
Monitoring of stormwater management treatment measures is undertaken occasionally to determine the level of treatment effectiveness	**C**
Stormwater management assets/treatment measures are not monitored	**D**
***** [1] Comprehensive stormwater management records are centrally collated, stored and analysed including for; water quality monitoring, stormwater management asset/measure effectiveness, data from working demonstration sites, stormwater management asset maintenance regimes and costs, stormwater management asset establishment and construction costs and non-compliance issues and remedies. Records are readily available and accessible for inclusion in local and regional performance reporting, to inform collaborative water quality improvement activities and enable continuous improvement and accelerated uptake of more effective management practices	**A**
Stormwater management records are kept by individual organisations including for; water quality monitoring, data from working demonstration sites, stormwater management asset/measure effectiveness and stormwater management asset maintenance regimes and costs. Records are made available to Council or regional healthy waters programs for collation and analysis for inclusion in local and regional reporting and to inform collaborative water quality improvement activities	**B**
Stormwater management records are kept by individual organisations including for; water quality monitoring, and stormwater management asset maintenance regimes. Records are made available to Council if requested	**C**
No stormwater management records are kept	**D**
***** [1] An integrated reporting process developed to effectively communicate environmental, social and economic outcomes delivered through urban stormwater quality management programs, including urban stormwater quality management plan (USQMP) actions, as part of a world class monitoring, modelling and evaluation program promoting and achieving water quality improvement	**A**
An integrated report card developed and delivered to communicate environmental, social and economic outcomes of stormwater quality improvement efforts	**B**
A report card developed to communicate environmental outcomes of stormwater quality improvement efforts	**C**
No effective water quality improvement outcome reporting	**D**

Note: ***** indicates the actions are also included in Developing Urban classification. [1] indicates the actions have been modified from the Developing Urban classification. NWQMS is the National Water Quality Management Strategy.

Appendix 6: Wet Tropics sugar cane INFFER analysis: Basin specific comparisons

Source: Park and Roberts (2014).

To explore differences in cost-effectiveness across individual basins, or combinations of basins, a set of alternative scenarios were assessed.

Scenario D: All sugar cane shifts to A practice in Johnstone, Tully-Murray and Herbert only

Scenario E: All sugar cane shifts to A practice in the Johnstone and the Tully-Murray only

Scenario F: All sugar cane shifts to A practice in Johnstone and Herbert only

Scenario G: All sugar cane shifts to A practice in the Johnstone only

Scenario H: All sugar cane shifts to A practice in the Herbert only

Scenario I: All sugar cane shifts to A practice in the Russell-Mulgrave, Johnstone, Tully-Murray and Herbert basins

Scenario J: All sugar cane shifts to B practice in the Russell-Mulgrave, Johnstone, Tully-Murray and Herbert basins

Scenario K: All sugar cane shifts to A practice in the Daintree-Mossman and Barron basins

Scenario L: All sugar cane shifts to B practice in the Daintree-Mossman and Barron basins

Scenario M – R: All sugar cane shifts to B Practice in individual basins

The following information on the relative DIN and PSII load contributions (Table 4) across each basin was used to estimate the proportion to which a shift to all A practice in each basin would contribute to the overall effectiveness of works, estimated at 0.10 across the whole Wet Tropics region. Basin scale load reductions are based on modelling results provided by Louise Hateley.

Table 1: Relative contributions from each of the Wet Tropics basins to total anthropogenic loads of DIN and PSII, together with assigned water quality risk rating from Waterhouse et al. (2014).

Basin	DIN		PSII	
	% of total anthropogenic load (12/13) (t/yr)	Risk ranking	% of total anthropogenic load (12/13) (kg/yr)	Risk ranking
Daintree-Mossman	6	5	5	5
Barron	2	6	4	6
Russell-Mulgrave	12	3	18	4
Johnstone	45	1	20	3
Tully-Murray	25	2	24	2
Herbert	10	4	29	1

Information on cane areas in each basin, together with basin specific adoption data was then used to estimate the cost associated with shifts to all A practice in each basin (Table 2). Finally, this data was integrated with other variables to estimate a BCR for each of the nominated scenarios, D – L.

Table 2: Estimated basin scale costs associated with shift to A class practice.

Basin	Total cane area (ABS data)	Area (ha) to be shifted to A practice	% of overall cost to be borne	Upfront costs (C) $M over 5 years	Annual maintenance costs (M) - $M/yr
Johnstone	19023	16170	14	4.7	0.9
Tully-Murray	24468	20798	18	6.0	1.2
Herbert	60674	51573	44	14.7	2.9
Russell-Mulgrave	20240	17204	14	4.7	0.9
Daintree-Mossman	6855	5827	5	1.7	0.3
Barron	6677	5675	5	1.7	0.3
Total	137937	117246	100	33.3	6.6

The results (Table 3) indicate that targeting effort towards individual basins or basin combinations is likely to be more cost-effective than a dispersed effort across the entire Wet tropics region.

Table 3: Scenario results for the sugar cane INFFER analysis in the Wet Tropics.

Scenario Code	Description – to achieve ERT for DIN with practice change in sugar cane only	DIN reduction (% of anthropogenic load)	DIN reduction – as a % relative to Scenario A	BCR variables					BCR	Comment
				W	F	A	C	M		
A	Shift to all A practice across all basins	28	100	0.10	0.87	0.5	33.3	6.6	0.49	Assumes ongoing incentive payments to compensate for adoption of A class practices by sugar cane farmers.
B	Shift to 50% A and 50% B practice across all basins	24	86	0.08	0.87	0.6	29.1	5.8	0.54	Up-front and maintenance costs have been reduced as a result of incentive payments only being required to shift 50% of sugar cane to A practice. Adoption value has been increased from 0.5 to 0.6. W has been reduced to 0.08 to account for lower impacts on water quality.
C	Shift to all B practice across all basins	19	68	0.06	0.92	0.8	13	2.6	1.3	Technical feasibility has been increased one category to 0.92 based on higher confidence related to proven practice and adoption has been increased to 0.8 given the apparent profitability of B class practice. As B class practices are understood to be profitable the upfront and maintenance costs do not include incentive payments. No incentive payments and slightly reduced extension and program delivery costs. W has been reduced to 0.06 because impacts are lower than for other scenarios.
D	Shift to A practice in Johnstone, Tully-Murray and Herbert only	22	80	0.08	0.87	0.5	25.4	5.0	0.52	
E	Shift to A practice in the Johnstone and the Tully-Murray only	20	70	0.07	0.87	0.5	10.7	2.1	1.08	
F	Shift to A practice in Johnstone and Herbert only	15	55	0.055	0.92	0.55	19.4	3.8	0.73	
G	Shift to A practice in the Johnstone only	14	45	0.045	0.92	0.6	4.7	0.9	2.02	
H	Shift to A practice in the Herbert only	3	10	0.01	0.92	0.6	14.7	2.9	0.14	
I	Shift to all A in the Russell-Mulgrave, Johnstone, Tully-Murray and Herbert basins	26	92	0.09	0.87	0.5	29.9	6.0	0.49	

Scenario Code	Description – to achieve ERT for DIN with practice change in sugar cane only	DIN reduction (% of anthropogenic load)	DIN reduction – as a % relative to Scenario A	BCR variables					BCR	Comment
				W	F	A	C	M		
J	Shift to all B in the Russell-Mulgrave, Johnstone, Tully-Murray and Herbert basins	15	54	0.06	0.92	0.8	11.7	2.3	1.43	
Scenario Code	**Description – to achieve ERT for DIN with practice change in sugar cane only**	**DIN reduction (% of anthropogenic load)**	**DIN reduction – as a % relative to Scenario A**	**BCR variables**					**BCR**	**Comment**
K	Shift to all A in the Daintree-Mossman and Barron basins	2	8	0.01	0.87	0.5	3.4	0.7	0.47	
L	Shift to all B in the Daintree-Mossman and Barron basins	1.5	5	0.005	0.92	0.8	1.3	0.3	0.98	
M	Shift to all B in the Daintree-Mossman	1.14	4	0.004	0.92	0.8	0.3	0.3	1.20	
N	Shift to all B in the Barron	0.38	1	0.001	0.92	0.8	0.3	0.3	0.3	
O	Shift to all B in the Russell-Mulgrave	2.28	8	0.008	0.92	0.8	0.9	0.9	0.80	
P	Shift to all B in the Johnstone	8.55	31	0.031	0.92	0.8	0.9	0.9	3.10	
Q	Shift to all B in the Tully-Murray	4.75	17	0.017	0.92	0.8	1.2	1.2	1.27	
R	Shift to all B in the Herbert	1.9	7	0.007	0.02	0.8	2.9	2.9	0.22	

Notes:

1. DIN reductions have been rounded off to the nearest whole number.
   BCR variables V, L, P and G were fixed at the original values assigned for the base case ERT.

terrain

NATURAL RESOURCE MANAGEMENT