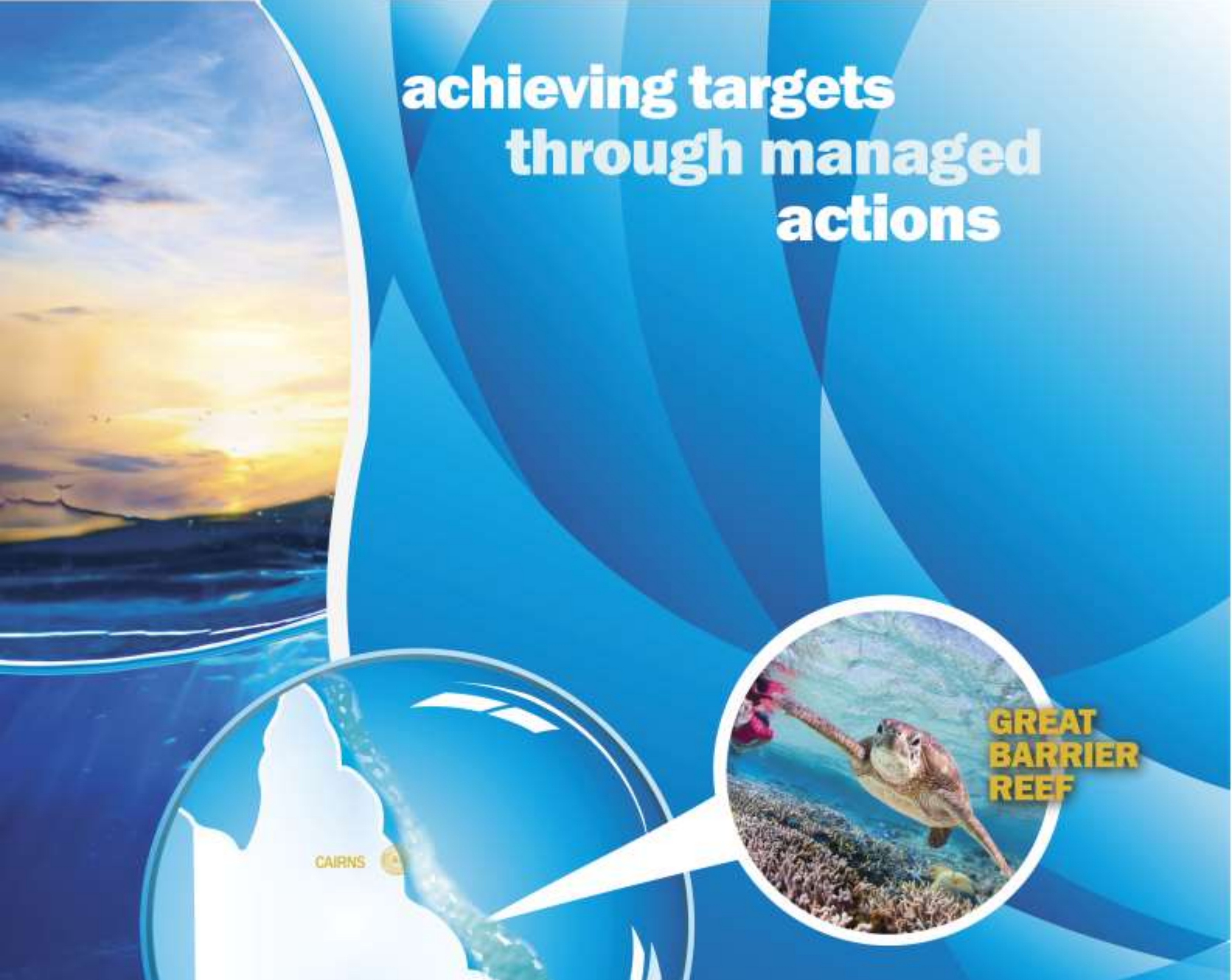

Water Quality Improvement Plan

For the Burnett Mary Region

Natural Decisions

Burnett Mary Regional Group
Practical Solutions for Natural Resource Management

Australian Government

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Acknowledgements

The Burnett Mary Regional Group for Natural Resource Management would like to thank the Australian Government Reef Programme for providing funding to support preparation of the Water Quality Improvement Plan (WQIP) for the Burnett Mary Region. 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 Frederick Bennett from BMRG and Michelle Dickson, Geoff Park and Anna Roberts from Natural Decisions Pty. Ltd. We are grateful for the input provided from a broad range of stakeholders and research providers over the last 12 months. In particular, we would like to acknowledge a number of individuals for their significant contributions: Jane Waterhouse, Jeffrey Maynard, Jon Brodie, Stephen Lewis, Caroline Petus, Eduardo do Silva, Dominique O'Brien, Caroline Coppo, Jane Mellors, Collette Thomas, Susan Sobtzick and Aaron Davis from TropWater, Craig Beverly (DEPI Vic), David Pannell and Graeme Doole (UWA), Ian Butler (UQ), Martijn van Grieken (CSIRO) and Kevin Bowden (BMRG).

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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.

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.

Executive Summary

The Burnett Mary region

The marine and coastal areas of the region include the southern-most part of the World Heritage listed Great Barrier Reef, the Ramsar listed Great Sandy Strait and the UNESCO designated Great Sandy Biosphere Reserve. These areas are renowned for their ecological importance and through tourism and fishing make a significant contribution to the regional and national economy.

The critical habitats of the marine and coastal areas include seagrass, soft sediments, coral reefs and coastal wetlands. These habitats are threatened by a range of factors including climate change, poor water quality, coastal development and fishing. While periodic cyclones can cause extreme stress and damage to these habitats, only the land-based activities can be managed to help protect the marine and freshwater ecosystems.

The Burnett Mary region has a catchment area of 53,000 ha with five river basins including the Baffle, Burnett, Kolan, Burrum and Mary. The population is approximately 290,000, the majority concentrated on the coastal fringes, and projected to reach 350,000 by 2026. Expansion is occurring in urban and horticultural land uses.

Water Quality Improvement Plans are being developed for each of the six Natural Resource Management regions within the catchment area of the Great Barrier Reef. This Water Quality Improvement Plan (WQIP) for the Burnett Mary region addresses the specific threat from increased loads of sediments, nutrients and pesticides from land based activities to the receiving marine and coastal assets of the Great Barrier Reef, the Great Sandy Strait and the Great Sandy biosphere.

The focus of the WQIP is on achieving the targets through management actions in the sugarcane and grazing industries, because there is a greater knowledge base than for other rural and urban land uses.

What values need to be protected?

The major ecological assets which need to be protected are seagrass meadows, coral reefs and mangroves and their dependent flora and fauna as well as the freshwater ecosystems in the catchment. The health of these ecosystems is critical to support human uses particularly tourism, recreation and fishing as well as fulfilling Australia's international environmental responsibilities.

To date there has been limited work on assessing the economic value of the Reef and connected ecosystems. Based on available knowledge, the preliminary present value of the entire Great Barrier Reef has been estimated to be in the order of approximately $26 billion.

What are the threats?

Marine and coastal ecosystems are impacted on by threats including water quality pollution from land based runoff (sediment, nitrogen, phosphorus and pesticides from rural and urban sources), coastal development, shipping/boating, fishing and climate change. Climate change poses the most significant threat to offshore coral reefs, whereas degrading water quality has most effect on inshore coral reefs and seagrass meadows. This in turn, affects dugong, cetaceans, turtles and seabirds.

Compared to pre-European conditions, the mean annual river loads of sediment and nutrient to the Reef have increased between two and nine times. The greatest risk posed to coral reefs and seagrass from degraded water quality is from the Mary basin (for sediment, nitrogen and phosphorus), followed by the Burrum (highest pesticide loads) and Burnett basins.   Overall the Mary basin poses by far the greatest challenge to the marine ecosystems.

How was the WQIP developed?

The Burnett Mary WQIP has been developed by bringing together existing science, completing new research and drawing the knowledge of technical experts and local stakeholders. The major pieces of work that have informed the WQIP include; development of water quality targets, financial economic analysis of management practices on cane and grazing land and development of an integrated bioeconomic model to assess the financial implications for these industries to meet water quality targets. The Investment Framework for Environmental Resources (INFFER) was used to assess the benefits and costs of achieving water quality targets and management scenarios in both cane and grazing.

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

Farm practice changes needed to meet quality targets

Two sets of targets were considered in this WQIP, the current Reef Plan targets which are formally endorsed by the Australian and Queensland governments, and the more recently developed Ecologically Relevant targets. The targets aim to address the water quality issues caused by human activity (anthropogenic). The parameters covered by the targets include total suspended sediments, dissolved inorganic nitrogen, dissolved inorganic phosphorus, particulate nitrogen, particulate phosphorus and PSII pesticides.

The '*ABCD*' water quality risk framework developed through the Paddock to Reef Monitoring and Modelling Program was used to assess the potential for management practices to reduce water quality impacts from land used for sugarcane and grazing. *A* refers to cutting-edge practices that require further validation, *B* is current 'best-management practice', *C* is common practices and *D* is superceded/below industry practice.

The economic analysis for both sugarcane and grazing incorporated local knowledge and assessment of non-financial barriers in assessing the attractiveness of practice adoption and considered this for typical farm sizes (small, medium and large). Moving from *D* to *C* and/or *B* practice was assessed as profitable on sugarcane farms of all farm sizes, although low levels of adoption would be likely on small farms. *A* practice adoption generally incurs a cost.

For grazing, all practices across all farm sizes were estimated to come at a cost, once non-financial related barriers were considered.   This suggests it will be extremely difficult to achieve practice change at large scale in the grazing industry without paying farmers to overcome profit and non-financial barriers for both paddock management practices and fencing of stream banks and gullies.

Net costs to sugarcane and grazing of meeting water quality targets

Analysis of both the Reef Plan targets and Ecologically Relevant targets was completed at two scales; at a regional scale where by different levels of water quality improvement were achieved in each basin but overall, the targets were met across the region. Or individual basin scale where by the water quality targets needed to be met in each river basin.

This analysis revealed that meeting targets at a whole of region scale was less costly than trying to meet them in each river basin, regardless of which set of targets were assessed. Reef Plan targets were almost 2.5 times more costly to achieve on an individual basin basis versus at the whole of region scale.

For both Reef Plan targets and Ecologically Relevant targets all sugarcane land is estimated to be required to move to at least B practice. In addition, for the Ecologically Relevant targets at the regional scale the majority of cane land (over 46,000 ha) is estimated to be required in A practice. This is because the water quality improvements achieved through the 'current best practice' is not sufficient to meet the water quality targets.

The picture in grazing land management is even more challenging, with more than 131,000 additional ha required in A practice for Reef Plan targets at the regional scale and almost twice that to achieve Ecologically Relevant targets. Riparian management and gully fencing predictions from the analysis were very low and are likely to be under-estimated and could be artefacts of the modelling assumptions.

Meeting Reef Plan targets across the Burnett Mary region

Whole of region scale Reef Plan targets were selected as the basis of developing the implementation plan for the WQIP. The approach to selecting the management practices is based on meeting the targets through the mix of practices that have the least cost and give the greatest water quality improvement. Because of the large costs to achieve load reductions in grazing, grazing areas are only targeted when load reductions cannot be achieved in sugarcane.

To achieve sediment targets large changes in land management practices are required from grazing dominated subcatchments in the Mary, Burnett and Kolan and to a lesser extent the Baffle and Burrum (Gregory River). Both cane and grazing are targeted for sediment load reduction; cane is targeted where other constituents can also be reduced and where practices are profitable.

Dissolved inorganic nitrogen load reductions need to come from the sugar cane growing areas in the lower Kolan, Burnett, Burrum (particularly Elliot and Gregory rivers) and the Mary catchments. High pesticide load reductions also need to come from sugarcane areas.

Benefit:cost analysis using INFFER

INFFER was used to assess overall benefits and costs associated with meeting water quality targets.

In addition to the direct costs to agriculture for the adoption of the required practice changes, there are other significant costs in administering a program of works and agency activities, and also some significant risks to achieve implementation.

Working towards achieving Reef Plan targets across the Burnett Mary region is estimated to cost $32.5 million over the first five years and is approximately three times as cost-effective as aiming for Ecologically Relevant targets which cost approximately $90 million over the first five years. Current political constraints (lack of guaranteed long-term funding and socio-political risks) were major reasons for calculated benefit:cost ratio figures of less than 1 (i.e. costs exceed benefits); if these risks could be reduced then benefits could exceed costs. Regardless, protecting the ecological values of the Great Barrier Reef, the Great Sandy Strait and the Great Sandy Biosphere require long term leadership and funding commitments by governments and participation by all responsible institutions as well as agricultural industries. The INFFER analysis supports the notion that Reef Plan targets are more realistic and acceptable for implementation than Ecologically Relevant targets, albeit still very challenging to both government and industry. For both sets of targets there is still considerable uncertainty about the level of benefits able to be achieved, but overall significantly increased funding will be required.

Delivery programs to implement the WQIP

The use of targeted, geographically specific extension and incentive programs in the cane and grazing industries currently will improve the effective use of government funding to achieve outcomes. While forestry, horticulture and urban areas are important, there is insufficient current information to assess the costs and effectiveness of required practice changes.

Within the region, the greatest risk posed to coral reefs and seagrass from degraded water quality is from the Mary basin (for sediment, nitrogen and phosphorus), followed by the Burrum (highest pesticide loads) and Burnett basins.   Overall the Mary basin poses by far the greatest challenge to the marine ecosystems.

The three main delivery mechanisms recommended are: 1) Positive incentives in the form of long-term incentive payments, referred to as stewardship payments; 2) Extension in the form of skills development and knowledge transfer will be required both as a stand-alone activity and to accompany the provision of incentive payments. This will require the development of clear and robust management agreements with landholders to ensure that mutual obligations are met over the long term; 3) Further research and development to fill knowledge gaps, particularly related to stream and gully erosion management.

To meet Reef Plan targets all sugar cane needs to move to A or B practice. Extensive changes are also required in the grazing industry – A practice management across 131,000 ha, from areas currently in B, C and D practices. Incentive programs and direct works in waterway fencing are also required, with most focus in the Mary catchment. Extensive grazing management practice change will be required to meet sediment targets; the relative emphasis on paddock, waterway and gully management is less certain; results are very sensitive to the current knowledge and assumptions used. There is a substantial need for additional research and development to better quantify waterway restoration hot spots, and for horticulture and urban impacts and potential for management.

In addition to funding required for direct actions on land, enabling actions are required to deliver the work plan of the WQIP. This includes project leadership and management, monitoring, evaluation, compliance auditing associated with stewardship programs, reporting and additional research to better address major knowledge gaps.

The modelling underpinning the WQIP assumes that water quality from land uses other than cane or grazing will not change over the implementation period. New (greenfield) developments in urban areas could increase overall loads of sediments delivered to streams and expanding horticultural land uses have significant potential to increase nutrient loads. Future planning needs to take this into account.

Based on international experience, underpinning regulations are likely to be an important component of water quality improvement programs, but have not been considered in this WQIP.Given that B class practices appear profitable, it is possible that if extension programs do not achieve practice change to B class, regulation might need to be considered in future, particularly for landholders remaining in D class practices.

Achieving the Reef Plan targets will require practice change programs at a larger scale than has occurred previously, and with different levels of extension and incentives than current programs. Continued careful consultation and partnerships with the relevant industries are needed to help understand the reasoning and logic behind the changes to current approaches.

Reasonable Assurance

This WQIP was developed using available published and unpublished information, technical expertise and local knowledge. Where significant knowledge gaps and uncertainties exist the assumptions made have been stated or it was acknowledged that there was insufficient information on which to make decisions. Aspects of the WQIP should be updated as part of an adaptive management process of learning and review as knowledge improves.

1 Introduction

The Burnett Mary region is one of six Natural Resource Management regions within the Great Barrier Reef catchment. The region has a catchment area of 56,000 km2 including the major river basins of the Baffle, Burnett, Kolan, Burrum and Mary, which collectively contribute over 2.4million ML of freshwater to marine ecosystems annually.

The marine and coastal areas of the region are extremely valuable and include the southern-most part of the World Heritage listed Great Barrier Reef Marine Park along with the Ramsar listed Great Sandy Strait and the Great Sandy bioregion which is designated by UNESCO.

The Water Quality Improvement Plan (WQIP) addresses the specific threat from increased loads of sediments, nutrients and pesticides from land based activities to the marine and coastal assets of the Burnett Mary region. It uses the current state of knowledge on which to base investment decisions linked to achieving regionally specific sediment, nitrogen, phosphorus and pesticide load reduction targets. Due to regional data limitations the focus of the WQIP is on achieving the targets through management actions in the sugarcane and grazing industries. There is a greater knowledge base for those two industries, with the remaining land uses (both rural and urban) only having local and incomplete datasets.

The Burnett Mary region (here after called 'the region') contains a diversity of freshwater, coastal and marine habitats, including the southern-most portion of the World Heritage listed Great Barrier Reef Marine Park and the Ramsar listed Great Sandy Strait. The region also contains the Great Sandy Biosphere, designated in 2009 by UNESCO in recognition of the international importance of its unique and iconic natural assets. As such the region hosts biodiversity values that are globally important beyond the Great Barrier Reef itself.

The region has an approximate catchment area of 56,000 km^2 and is approximately 12% of the total contributing catchment area draining into the Great Barrier Reef lagoon (423,122 km^2) (Burnett Mary Regional Group, 2005b, Fentie et al., 2014). There are five major river basins, from north to south, being the Baffle, Kolan, Burnett, Burrum and Mary.

The marine areas of the region support over 15,000km^2 of seagrass meadows and unique near shore and offshore coral reef communities, providing habitat for a number of iconic species including dugong and humpback whales, and five species of endangered and vulnerable marine turtles (Coppo et al. 2014; Waterhouse et al. 2014). These marine ecosystems support significant commercial and recreational fisheries targeting fish and spanner, mud and blue swimmer crabs, scallops and prawns (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b).

1.1 Why is a Water Quality Improvement Plan needed?

The health of the coastal and inshore marine ecosystems of the region are influenced by the quality and quantity of runoff from the five river basins of the region. Increased loads of nutrients, sediments and pesticides from adjacent catchments have led to chronic changes in environmental conditions for Great Barrier Reef species and ecosystems (Kroon et al. 2013), and there are severe but episodic changes after extreme river floods (Schaffelke et al. 2013). Monitoring of seagrass beds in the Great Sandy Strait indicates that the recovery of deep water species is limited following active wet seasons and associated increased sediment loads (Walker & Esslemont 2008).

Understanding the effects of water quality changes on marine species and ecosystems of the Great Barrier Reef has improved considerably over the last decade due to a focused research effort and ongoing monitoring (Schaffelke et al. 2013). There is improved knowledge about the relationships between water quality change and ecosystem health for corals, seagrass species and mangroves which has informed the development of ecologically relevant targets for water quality improvement (Schaffelke et al. 2013).

To help protect ecosystem values, the Burnett Mary Regional Group (BMRG), with funding from the Australian Government, has developed a Water Quality Improvement Plan (WQIP). The development of this WQIP has consolidated and updated three previous catchment based WQIPs (Burnett-Baffle, Burrum and Mary), acknowledging the ecological links between the two major marine protected areas in the Burnett Mary region.

This WQIP will help guide investment in activities to address water quality issues related to rural land use and to a lesser extent urban areas[1]. It explicitly considers the feasibility, benefits and costs of achieving water quality objectives on agricultural land and identifies the research and monitoring required to improve knowledge.

1.2 Overview and scope

WQIP's are being developed or updated for the six coastal Natural Resource Management regions (Cape York, Wet Tropics, Burdekin, Mackay-Whitsunday, Fitzroy and Burnett Mary) associated with the Great Barrier Reef Water Quality Protection Plan (the Reef Plan). Actions across the entire Reef are required to meet Reef Plan targets for water quality improvement.

Within each WQIP, marine ecosystem targets are linked to end-of-river pollutant (suspended sediments, nutrients and pesticides) load targets. Each region is different in terms of land use, current management practices and other physical attributes like soil type, terrain and climate. Each region, therefore, contributes differently to the overall targets.

A number of regions have previously established regionally specific water quality and groundcover targets through WQIP's. To ensure consistency with the broader Reef Plan targets, water quality improvement planning processes should consider the Reef Plan's long term goal and use consistent modelling and monitoring information to set regional targets that align with Reef Plan (Secretariat Reef Water Quality Plan Protection 2013).

The Burnett Mary WQIP identifies the main issues impacting the marine and coastal ecosystems from land-based activities, and identifies and prioritises management actions to improve water quality outcomes. The WQIP cannot address all the issues related to threats and water quality in the region, but focusses on those where there is sufficient knowledge to develop actions. The WQIP also identifies where there are knowledge gaps and has developed priorities and actions for issues where there is a good level of current knowledge of both the water quality issues and the actions that can be implemented to address the issues.

[1] This is not because urban areas are less important, there is less detailed quantitative information available on which to base investment decisions upon based on benefits and costs.

The focus of the WQIP is on protecting the marine and coastal ecosystems, although it is recognised that the implementation of management actions that reduce loads of pollutants will also have a benefit for freshwater ecosystems in the catchment. Priorities for freshwater systems will need to be developed through a separate process drawing on existing knowledge outlined in this WQIP.

In this context the WQIP provides a comprehensive plan for the Burnett Mary region. It is the result of an integrated assessment of the benefits and costs of reaching water quality targets for the five river basins in the region (Baffle, Burnett, Kolan, Burrum and Mary) through the use of contemporary biophysical, economic and social data. The process has considered both Ecologically Relevant Targets and the Reef Plan’s long term goal and consolidates and updates the previous catchment based WQIPs.

1.2.1 Catchment and marine boundaries

The marine boundary defines the limit of ecological marine assets considered for the WQIP. The marine boundary incorporates the Great Barrier Reef Marine Park in the north and the Great Sandy Strait Marine Park in the South. In the north, the boundary extends north-east from Tannum Sands and then follows the Great Barrier Reef Marine Park boundary to its south-eastern point. The boundary then heads directly to Sandy Cape on the northern tip of Fraser Island and follows the western boundary of the Island to incorporate the Great Sandy Strait. Fraser Island itself has been excluded from the scope of this WQIP.

The catchment area considered for this WQIP includes the catchments of the major river basins of the Burnett Mary region including the Baffle, Burnett, Kolan, Burrum and Mary. The catchment area of Noosa, Maroochy and Mooloola Rivers (considered for some purposes to be part of the Mary River basin) have been excluded from the scope of the WQIP.

1.2.2 Freshwater ecosystems

The major focus of Reef Plan and this WQIP is on marine and coastal ecosystems, and addressing the water quality threat from land-based activities. However, these ecosystems also receive numerous ‘ecosystem services’ from tributary waterways and upstream environments (Davis & Brodie 2014). A key conclusion of the ‘Scientific Consensus Statement’ for the Great Barrier Reef was that the health of freshwater ecosystems in the catchment is impaired by agricultural land use, hydrological change, riparian degradation and weed infestation.

The WQIP does not attempt to prioritise freshwater ecosystems or describe management activities to address the threats to these systems. This would require a separate process that brings together existing policy frameworks including the Environmental Values and Objectives for designated waters together with knowledge on the connectivity of these ecosystems and their condition from the Aquatic Biodiversity Assessment Mapping Method (AquaBAMM) (Queensland Government 2014a), Conceptual models of freshwater ecosystems (Davis & Brodie 2014) and the Coastal Ecosystem Assessment Framework developed by the Great Barrier Reef Marine Park Authority (GBRMPA 2012) as well as other relevant local knowledge and studies.

1.2.3 Sediment, Nutrient and Pesticide Loads

The WQIP addresses the specific threat from increased loads of sediment, nutrients and pesticides from land based activities to the region’s marine and coastal ecosystems.

Other threatening processes will also have an impact. These threats include resource utilisation and climate change, which are very important but not able to be included within the scope of this WQIP.

1.3 Approach, supporting projects, previous work

This WQIP was developed in accordance with the Framework for Marine and Estuarine Water Quality Protection (Department of Environment Water Heritage and the Arts 2002). The WQIP details the ecological values of coastal, estuarine and freshwater systems and outlines water quality objectives to protect these values. The identification and quantification of land-based priority pollutants is a key component of the WQIP and the proposed reduction of pollutants to a defined maximum load is critical in meeting the water quality objectives.

This WQIP involved the following interrelated activities:

- Development and assessment of two sets of targets; one set based on Reef Plan 2013 (Reef Plan Targets, RPTs) and another based on the ecological requirements of the marine assets (Ecologically Relevant Targets, ERTs).
- Comprehensive risk assessment of connectivity between the marine and terrestrial assets in the Burnett Mary region.
- Identification of ecological and economic values of the marine coastal areas of the Burnett Mary.
- Coordination of science and other knowledge on urban and rural pollutants.
- Financial and economic analysis of the profit and costs associated with adoption of management practices in the sugarcane and grazing industries.
- Bioeconomic modelling to assess the management actions required and associated costs in attaining targets.
- Benefit:Cost analysis using the Investment Framework for Environmental Resources (INFFER™).

1.4 Governance and stakeholder engagement

The development of the Burnett Mary WQIP was led by the Burnett Mary Regional Group (BMRG) with funding from the Australian Government, and input from Queensland agencies and local stakeholders.

The BMRG worked collaboratively with leading consultants and research organisations to complete supporting technical work and development of the WQIP. The WQIP process was overseen by a technical panel consisting of scientists, government, and industry and community representatives.

Engagement with regional experts and stakeholders occurred throughout the development of the plan through the supporting projects and public consultation.

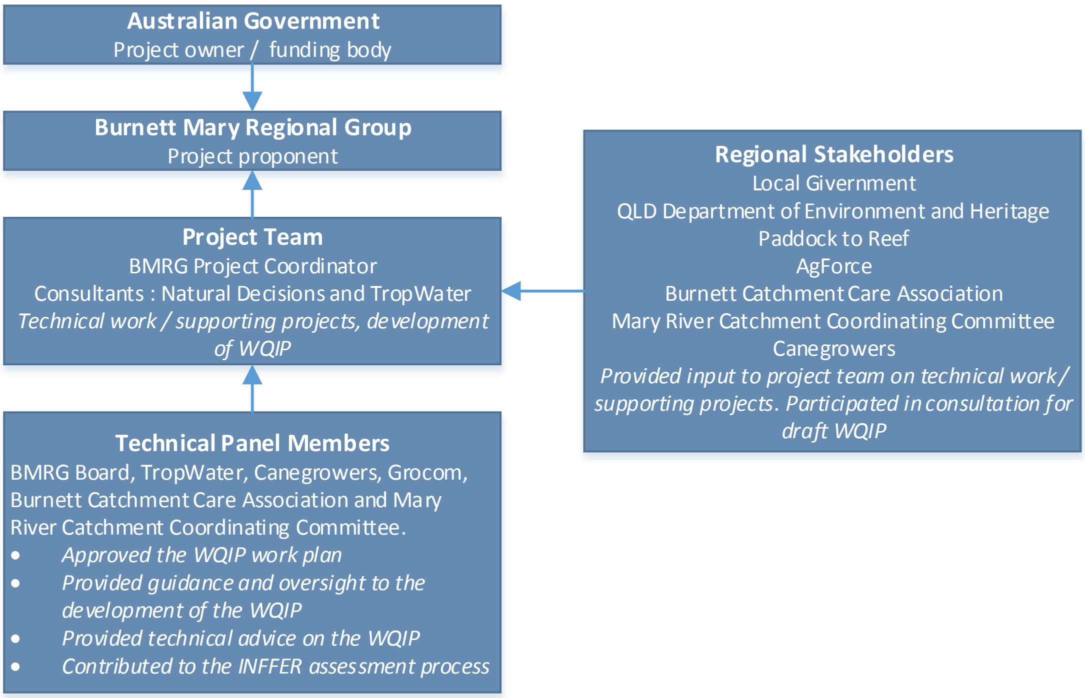


Figure 1. Governance arrangements for the Burnett Mary WQIP

1.5 Queensland Legislation and Policy

This WQIP follows the framework described in the National Water Quality Management Strategy (Department of Environment Water Heritage and the Arts 1992), the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000) and healthy waters management plan guideline in Queensland. In Queensland, the Environmental Values and Water Quality Objectives (EVs/WQOs) framework is linked through the *Environmental Protection (EP) Act 1994* (Anon 1994) to the *Environmental Protection (Water) Policy 2009* (Anon 2009) and *the Environmental Protection Regulation 2008* (Anon 2008).

The EPP Water includes the following components of the EVs /WQOs setting process:

- consulting the community to identify waterway uses (e.g. irrigation, stock watering) and values (e.g. aquatic ecosystem, cultural and spiritual) – i.e. EVs
- identifying management goals (quantitative measures or narrative statements that may be used to assess whether EVs are maintained) for Queensland waters
- stating water quality guidelines and water quality objectives (WQOs) to enhance or protect the EVs
- providing a framework for making consistent, equitable and informed decisions about waters that promotes efficient use of resources and best practice environmental management
- involving the community through consultation and education.

Further details on EVs and WQOs are available from the EHP website, including the following fact sheet http://www.ehp.qld.gov.au/water/pdf/factsheet-evs-wqos-epp-water.pdf

The EPP Water identifies a framework for using the best available information to derive WQOs based on the EVs and best available water quality guidelines (with preference given to local information sources). In the absence of suitable local information, the next best available information source applies. For aquatic ecosystem EV's, guideline sources may include the Queensland water quality guidelines, the Water quality guidelines for the Great Barrier Reef Marine Park (GBRMPA) and ANZECC (2000) water quality guidelines. For human water uses, relevant national guidelines typically apply (e.g. ANZECC, NHMRC).

EVs and WQOs have been included in Schedule 1 of the EPP (Water) for the Mary and Burrum River basins, Fraser Island, Hervey Bay and Great Sandy Strait. These include mapping of waters identified for high ecological value level of protection in fresh, estuarine and coastal/marine waters. Documents and plans are available from the EHP website at http://www.ehp.qld.gov.au/water/policy/schedule1/mary_river_basin_great_sandy_region_scheduled_evs__wqos.html .

For waters not scheduled under the EPP Water, mapping of waters identified for high ecological value level of protection was included in the original Burnett-Baffle WQIP (Fig 4.2) and is included in Appendix 5 of this WQIP. Draft EVs/WQOs (based on the earlier WQIP and updated where necessary) are included in this WQIP for Burnett, Baffle, Kolan and associated waters (refer Appendix 5). These will be subject to further review by the Department and GBRMPA as part of the process to finalise EVs/WQOs under the EPP Water for this region. WQOs for open coastal/marine waters in the GBR will be reviewed in consultation with GBRMPA, with reference to GBRMP water quality guidelines and local data.

Use of EVs/WQOs

EVs/WQOs are used in a variety of planning and decision making processes, including:

- Decisions on point source (e.g. industrial) development. Under the EP Act, certain activities with the potential to release contaminants into the environment are referred to as environmentally relevant activities (ERAs). These often involve a discharge or outflow from an identifiable location, such as a pipe. The EP Act (standard criteria) and section 51 of the Environmental Protection Regulation 2008 establish requirements for the proponent and the administering authority to consider and assess impacts of ERAs on EVs/WQOs under the EPP Water. Further details are provided in departmental guidelines:
  - http://www.ehp.qld.gov.au/era/water-impacts-em963.pdf
  - http://www.ehp.qld.gov.au/licences-permits/business-industry/pdf/wastewater-to-waters-em112.pdf
- Urban diffuse emissions. The State Planning Policy (State interest—water quality) under the *Sustainable Planning Act 2009* (SP Act) seeks to ensure that that 'the environmental values and quality of Queensland waters are protected and enhanced'. Details on how EVs/WQOs are considered in decision making are outlined in the SPP (State interest – water quality), available from http://www.dlg.qld.gov.au/about-planning/state-planning-policy.html
- Agricultural diffuse activities. Best Management Practice (BMP) approaches for rural industry activities have been adopted as the key policy approach towards improved rural land management (including under the Reef Water Quality Protection Plan 2013). BMPs provide important mechanisms to assist planning and decision-making towards the

protection and enhancement of local EVs and WQOs under the EPP water. Examples of BMP codes *include those for sugar* cane and grazing activities.

Currently there is insufficient information at the scale required to assess whether water quality concentrations in the catchment are maintaining the use values as required under the EPP Water (2009). The targets used in this WQIP are average annual load based targets which have limited relationship with concentration based targets (temporal and spatial) required to adequately assess whether use values have been maintained.

The EPR provides a regulatory regime for Environmentally Relevant Activities[1] that have the potential to impact on water quality, including, but not limited to agriculture, aquaculture, mining, and waste disposal. The EP Act also sets monitoring requirements related to release of wastewater at a regional and local scale. The WQIP is required to meet the legislative requirements under the EPP Water. This WQIP is limited to agriculture and, to a much lesser extent, urban impacts. Additional legislative and policy context that is relevant to the development and implementation of the Burnett Mary WQIP is included in Appendix 1.

1.5.1 The Great Barrier Reef Water Quality Protection Plan

The policy context of the Great Barrier Reef in particular is summarised in the Reef Water Quality Protection Plan (Reef Plan). Reef Plan is a collaborative program of coordinated projects and partnerships designed to improve the quality of water in the Great Barrier Reef though improved land management in reef catchments. Both the Australian and Queensland Governments have committed to Reef Plan and oversee its implementation (Secretariat Reef Water Quality Plan Protection 2013).

Reef Plan sets targets for improved water quality and land management practices and identifies actions to improve the quality of water entering the waters of the Great Barrier Reef.

Initially established in 2003, the plan was updated in 2009 and 2013. It details specific actions and deliverables. It incorporates and supports the actions of industry, community groups and government that impact on reef health and links with a number of other legislative and planning initiatives. The actions in Reef Plan are aimed to be completed by 2018 when Reef Plan will be reviewed.

The development of Reef Plan was guided by the Scientific Consensus Statement (Schaffelke et al. 2013) which shows that poor water quality is continuing to have a detrimental effect on Reef health.

1.5.2 Reef 2050 Plan

The Australian and Queensland governments are working together to develop a Long-Term Sustainability Plan for the Great Barrier Reef World Heritage Area to guide the protection and management of this iconic World Heritage Area to 2050.

The World Heritage Committee has requested that Australia: "...undertake a comprehensive strategic assessment of the entire property, identifying planned and potential future development

[1] Environmentally Relevant Activities (ERAs) are activities that will, or have the potential to, release contaminants into the environment that may cause environmental harm.

that could impact the Outstanding Universal Value to enable a long-term plan for sustainable development that will protect the Outstanding Universal Value of the property." (Anon n.d.).

The Plan will inform future development by drawing together the marine and coastal components of the comprehensive strategic assessment, providing an over-arching framework to guide the protection and management of the Great Barrier Reef World Heritage Area from 2015 to 2050. It will target the identified areas of action from the strategic assessments and seek to address gaps important for future management of the area.

2 Catchment characteristics

The major primary industries in the region are grazing, sugarcane, horticulture, forestry, commercial fishing and mining. Grazing and conservation are the dominant land uses on an area basis, and are associated with drier inland regions. Sugarcane, horticulture and cropping along with urban areas dominate the more easterly coastal zones. The major urban areas are the cities of Bundaberg, Hervey Bay, Gympie and Maryborough.

The climate is sub-tropical with a summer dominant rainfall and with significant variability across the region due to elevation and distance from the coast. Average rainfall varies from over 2,000 mm/year in the south east Mary basin to less than 650 mm/year in the far western Burnett. The modelled average annual flow for the whole region is 2.4 million ML / year, representing 3.8% of the average annual inflow to the Great Barrier Reef, the lowest discharge of the six Great Barrier Reef regions.

While periodic cyclones can cause extreme stress and damage to the Reef structure and other communities, such as seagrass meadows, only the land-based activities can be managed to help protect the marine and freshwater ecosystems.

The region's population is approximately 290,000, the majority concentrated on the coastal fringes, and projected to reach 350,000 by 2026. Expansion is occurring in urban and horticultural land uses. An ageing population, declining sugar and beef industries, higher unemployment and lower overall socio-economic circumstances may pose greater challenges to the adoption of management changes to improve ecological values compared to other regions in the Great Barrier Reef catchments, especially in the Burnett and Baffle basins.

These trends present significant challenges for sustainability, particularly in managing the increased pressure on the natural resources and community services.

2.1 Location and landscape

The Burnett Mary region covers 56,000 km^2 (5.6 million ha) of land and includes five major river basins (Baffle, Burnett, Burrum, Kolan and Mary). Collectively the five river basins total some 53,000km^2, the largest being the Burnett followed by the Mary (Fentie et al. 2014). The Baffle, Kolan and the Burnett basins flow to the Great Barrier Reef Marine Park whilst the Burrum and Mary flow to the Great Sandy Strait Marine Park.

The upper Burnett is an outback landscape, supporting a variety of pastoral, forestry and mining pursuits. In the lower Burnett the floodplain supports extensive areas of sugarcane and horticulture. Sub-tropical landscapes with both pastoral and horticultural land uses occur in the Mary basin and the adjoining coastal zone supports tourism and fishing activities.

In addition to the major primary industries (grazing, sugarcane, horticulture, forestry, commercial fishing and mining) the Burnett Mary region also contains major urban areas, including the cities of Bundaberg, Hervey Bay, Gympie and Maryborough. The southern part of the Great Barrier Reef World Heritage Area occurs within the region, as does the UNESCO designated Great Sandy Biosphere, and the Great Sandy Strait, a wetland of international significance. The marine area includes Lady Elliot, Lady Musgrave and other islands of the Capricorn Bunker Group. Fraser Island forms a barrier to the Great Sandy Strait creating unique inshore habitats (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b).

2.2 Climate

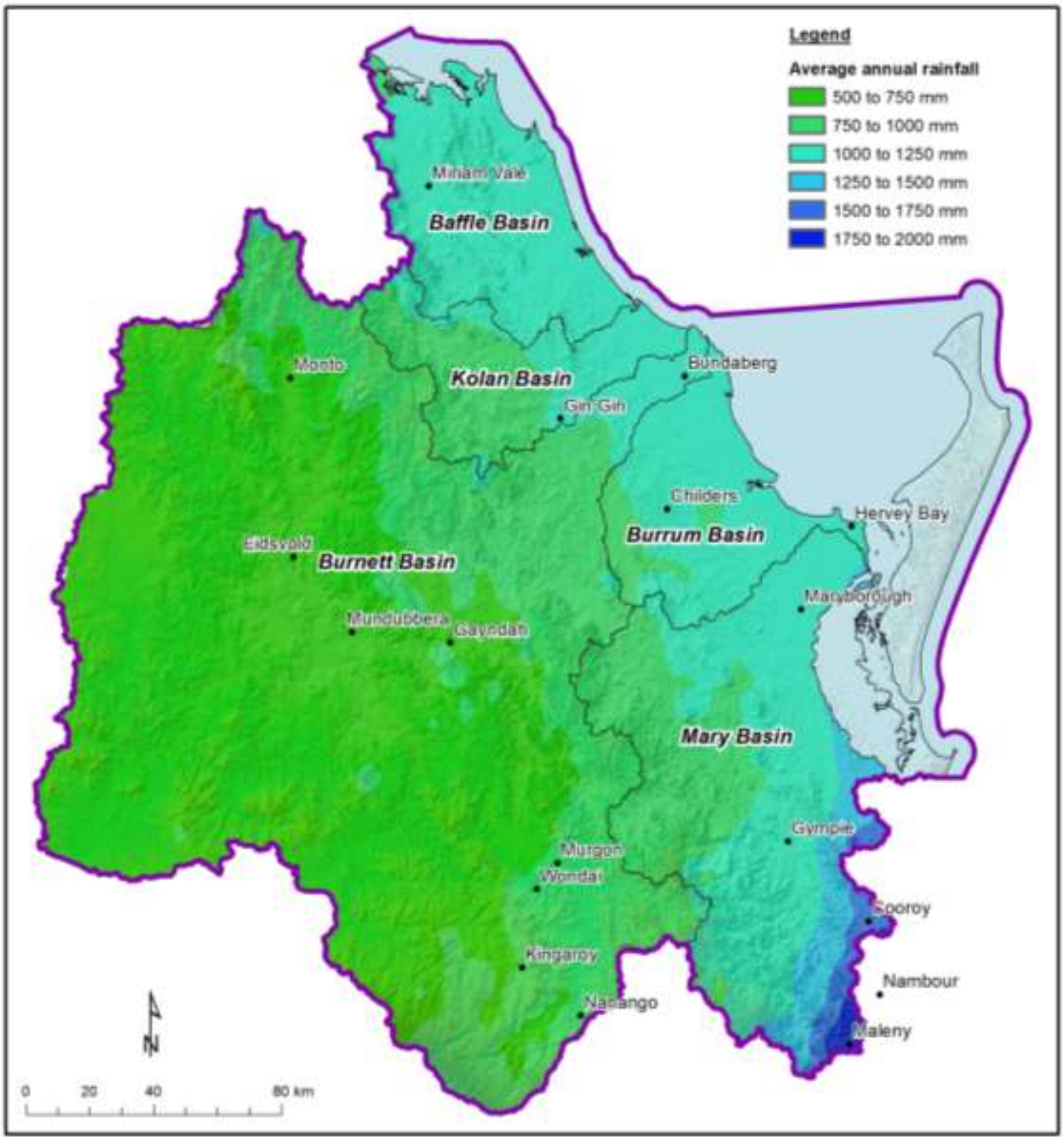


Figure 2. Rainfall distribution in the Burnett Mary region

The climate of the Burnett Mary region is sub-tropical with a summer dominant rainfall. There is significant variability in climate across the region due to elevation and distance from the coast (see (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b)). Summer dominant rainfall is influenced by cyclonic weather patterns which develop in coastal tropical Queensland, whilst weather fronts and depressions from the South and West bring winter and spring rain. Annual rainfall varies from over 2000mm in areas of the Blackall Range in the upper Mary to less than 650mm annual rainfall in the far west of the region (Fentie et al. 2014).

The annual rainfall distribution along with temperature is a significant factor in determining agricultural land uses and productivity. Grazing land systems dominate in the drier western areas and cropping, horticulture and dairying are more prevalent in the eastern and southern range areas. However, winter rains in the western part of the region are generally sufficient to produce winter cereals and forage crops, particularly on land under summer fallow. In the west, summer storms are also essential to maintain surface supplies of water for stock (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b).

2.3 Cyclones, storms and flooding

Conditions in terrestrial catchments are most strongly connected with marine receiving waters during floods but the extreme rainfall causing major floods is often episodic and may be separated by decadal droughts. Consequently, there are inherent and complex lags in this system (Secretariat Reef Water Quality Plan Protection 2013).

Cyclones can cause extreme damage to reef structure and other communities, such as seagrass meadows (Australian Government & Queensland Government 2014). In 2010, a historically strong La Niña weather pattern developed, replacing an El Niño. Between 2009 and 2012, seven cyclones affected North Queensland which resulted in substantial physical damage to rivers and floodplains with the 2013 flooding, the Burnett River broke historical records (Simon 2014). Extreme rainfall in 2010-2011 and 2012-2013 resulted in extensive flood plumes along most of the coast and across much of the continental shelf in some regions (Jon Brodie et al. 2013).

The cumulative impacts of extreme events, such as floods, tropical cyclones, crown-of-thorns starfish outbreaks and thermal stress act to exacerbate the chronic impacts of poor water quality, which remains a major driver of change. Ultimately, extreme events will be difficult to manage directly and together with chronic poor water quality can erode the ability of ecosystems to cope with or recover from future disturbances and change.

Improving water quality entering the marine and coastal ecosystems from the catchment however can be managed and will be a critical resilience strategy in the face of increasing intensity of extreme events and ocean acidification.

2.4 Geology, soils and topography

The Burnett Mary region consists of a number of geomorphic environments including coastal plains, undulating hills and inland hills and plateaus.

The dominant features of the coastal areas are the coastal sand masses of the Fraser and Cooloola coasts (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b). Acid sulphate soils, and remnant beach ridges and dunes are found along a narrow low marine plain adjacent to the coast. Acid drainage has affected water quality in this area (Fentie et al. 2014).

The coastal plains and the undulating landscapes that separate the plains from the inland areas extend 50km inland and consist of a range of old geologies – many of which are highly weathered.

In this landscape there are sandy to loamy texture contrast soils, formed from deeply weathered sedimentary rocks on a relatively flat broad plain west of the marine plain.

Narrow floodplains consisting of deep fertile dark soils have formed along the major rivers and deep red soils formed from young volcanic rocks east of Bundaberg (Fentie et al. 2014).

The inland areas west of the coastal plain make up most of the region and are dominated by rolling hills and plateaus. The geology of this area consists of:

- Clay soils formed from basic volcanic rocks on hills
- Sandy soils formed from granite rocks on hills. Some have sodic subsoils and are erodible
- Deep red soils formed from deeply weathered volcanic rocks on plateaus
- Brown or grey sandy or loamy texture contrast soils formed from deeply weathered granitic or sedimentary rocks on plateaus. Some have sodic subsoils and are erodible.

In the far west, a ring of mountain ranges or high plains forms the boundary between the coastal catchments and the Murray Darling Basin. In this landscape there are loamy texture contrast soils and dark cracking clays. These loam based soils formed on sedimentary, volcanic, acid intrusive and metamorphic rocks on the ranges. Most of these soils have sodic subsoils and are erodible while the dark cracking clays formed on elevated relict alluvial plains at Durong (Fentie et al. 2014).

2.5 Hydrology

The region experiences a highly seasonal rainfall, and as such, a seasonal pattern in flow. A distinct wet season occurs during December to June, with peak river flows typically occurring during the same period. Low flows are recorded during the dry season (August to November), with flow ceasing altogether in some places.

During the dry season, many of the rivers have disconnected waterholes, although some may be connected by minimal subsurface flow (Fentie et al. 2014).

The modelled average annual flow for the Burnett Mary region is 2.4 million ML / year. This represents 3.8% of the average annual inflow to the Great Barrier Reef and is the lowest discharge of the six Great Barrier Reef regions. Catchment modelling for the region estimates that the Mary basin has the highest annual average flow (1.4 million ML/yr), followed by the Baffle (490,000 ML/yr), Burrum (259,000 ML/yr), the Kolan (193,000 ML/yr) and Burnett (74,000 ML/yr).

In terms of contribution of flow per unit catchment area, the Burnett has the lowest runoff per unit area (6ML/km^2/yr), while the Mary and Baffle basins have the highest runoff per unit area (150ML/km^2 and 122 ML/km^2 respectively) (Fentie et al. 2014).

Table 1. Rainfall and modelled runoff and flow by basin (from Fentie et al. 2014)

Basins	Area (km^2)	Rainfall (mm/yr)	Runoff (mm/yr)	Runoff coefficient (%)	Flow (ML/yr)
Baffle	4,035	994	125	13	491,201
Burnett	33,038	652	33	5	74,321
Kolan	2,955	831	73	9	193,141
Burrum	3,450	862	89	10	258,813
Mary	9,340	1,021	174	17	1,400,239

At a local level, large portions of the stream length within the Burnett and Kolan basins are regulated and experience more constant flows than would have occurred naturally, while some tributaries are intermittent and only flow after rainfall (BMRG, 2009).

2.6 Land use

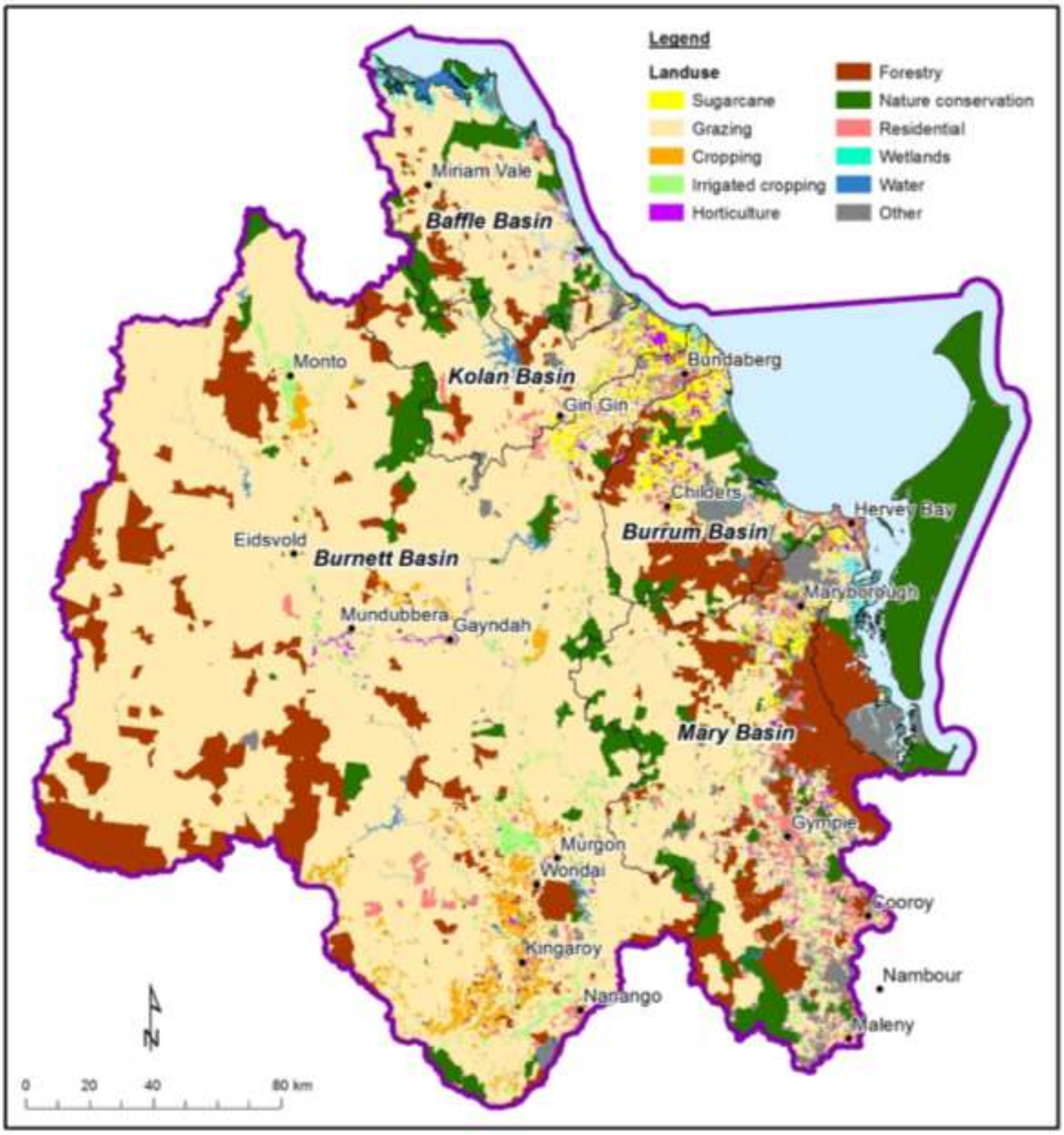


Figure 3 Major land uses in the Burnett Mary region

Information from the 2009 land use map from the Queensland Land Use Mapping project (QLUMP) (DSITIA 2012) was used as the basis of the Source Catchment modelling completed for the Burnett Mary region. QLUMP land use data together with Australian Bureau of Statistics data has been used to inform this WQIP. QLUMP data has been used to represent all land uses with the exception of sugar cane where ABS data has been used because it is more widely accepted by local stakeholders as representing the current cane area. Table 2 and Figure 3 and Figure 4 show the land uses in the region.

Table 2 Land use areas for the Major River basins of the Burnett Mary region.

Land use (Area in ha.)	River basin					
	Baffle	Burnett	Burrum	Kolan	Mary	All basins
Sugar cane[1]	*5,419*	*10,159*	*15,718*	*11,078*	*9,470*	***51,844***
Grazing	271,460	2,550,451	128,790	203,501	472,326	**3,626,528**
Conservation	75,396	131,552	72,084	26,473	166,165	**471,670**
Forestry	28,084	404,490	76,506	26,473	192,623	**728,176**
Dryland Cropping	132	81124	399	157	197	**82,009**
Irrigated Cropping	489	40,875	587	714	3,885	**46,550**
Horticulture	1,559	10,223	6,576	3,220	7,972	**29,550**
Residential and Farm Infrastructure	7,197	36,881	15,594	9,757	53,926	**123,355**
Water	17,603	19,093	9,380	9,879	11,541	**67,496**
Other	780	9,256	3,395	344	6,292	**20,067**

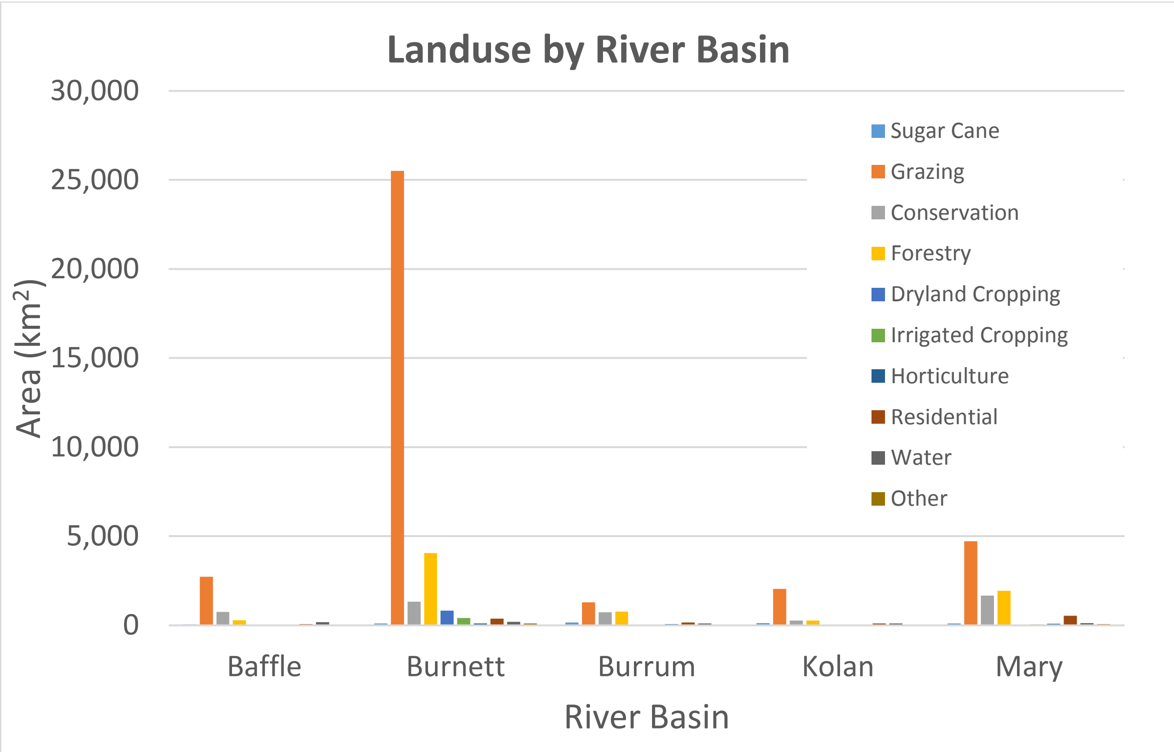


Figure 4. Land use areas by river basin the Burnett Mary Region

Grazing and conservation are the dominant land uses. Sugar cane, irrigated and dryland cropping are also present along with horticulture, and urban land uses. Land uses are strongly correlated with soil

[1] Note that data on Sugar cane areas has been sourced from (Australian Bureau of Statistics 2014) because the figures are much more in line with industry estimates of land use. There is a significant difference between the QLUMP and ABS estimates for sugar cane.

type and variation in rainfall. Grazing is dominant across all river basins, with the largest area in the Burnett. In the Mary basin forestry, conservation and urban areas in addition to grazing are the dominant land uses, with some horticulture including macadamias in the Gympie area (Fentie et al. 2014).

In the Burnett basin horticulture is largely restricted to irrigated orchards in the Gayndah and Mundubbera areas, and to vegetable and tree crops within the Bundaberg irrigation area.

Mining of black coal, gold, kaolin and limestone occupies a very small land area in the region, but makes a significant contribution to the economy. Eco-based tourism has grown strongly in recent decades, especially the backpacker market, focused on Bundaberg and Gaydah (Marsden Jacob & Associates 2013).

2.7 Socio-economic profile

An understanding of the social and economic profile of the region provides important contextual information on the likely growth areas and demographics of the Burnett Mary region. Recent socio-economic studies (Marsden Jacob & Associates 2013; Queensland Treasury and Trade 2014) have considered these issues for the majority (although not all) of the catchment areas within the Burnett Mary region[1].

The Marsden Jacob and Associates (2013) report (Marsden Jacob & Associates 2013) outlines that the populations of the Burnett and Baffle basins are expanding at a slightly faster rate than the Reef catchment population as a whole. With the exception of some areas where population growth is driven by mining, the bulk of the future population growth is likely to occur in the coastal zone.

Queensland Treasury and Finance (2014) statistics for the Wide Bay Burnett (which is the major part of the Burnett Mary region) indicate that the majority of the population (60.2%) falls in the 15-64 age bracket. When compared to the statistics for all of Queensland, the Wide Bay Burnett has a higher percentage of older residents (20.4% compared with 13.3% for all of Queensland). The median age of residents is also higher; in the Wide Bay Burnett the median age is 43.6 compared with 36.6 for all of Queensland.

Queensland Treasury and Finance statistics for unemployment indicate a higher unemployment rate in the Wide Bay Burnett region (8. 5%) compared with all of Queensland (5.9%) (Queensland Treasury and Trade 2014). In a separate study of Reef catchments it was noted that social conditions in the Burnett and Baffle basins are notably lower than the Reef as a whole (Marsden Jacob & Associates 2013).

This study noted that a combination of factors, an ageing population, higher unemployment and lower overall social conditions, poses an additional challenge to the adoption of management changes to improve ecological values (Marsden Jacob & Associates 2013).

[1] Marsden Jacobs Associates have considered the basins that fall within the Reef and Queensland Treasury and Trade have considered the entire region with the exception of the Agnes Water area.

Agriculture in the region has changed significantly in recent years, with declines in the contribution of traditional industries such as sugar and dairy and expansion in horticulture and beef. Horticultural development is a major focus for future growth (Marsden Jacob & Associates 2013).

The high reliance on agriculture, particularly beef and sugar, as a source of employment and income within the Burnett and Baffle basins and the associated water quality risks from production are likely to continue without policy intervention.

2.8 Basin Summaries

A summary of the major land uses and population size for each basin is provided below.

2.8.1 Baffle

The Baffle basin comprises the small coastal river system of Baffle Creek, together with a number of smaller creeks which also drain to the coast. The Baffle basin is relatively small (404,000ha) accounting for only 8% of the region area (Fentie et al. 2014) and has a population of approximately 6100. The area is bounded by the Many Peaks and Bobby Ranges in the west and the Dawes and Watalgan Ranges in the south. The coastal area is adjacent to the southern end of the Mackay/Capricorn Section of the Great Barrier Reef Marine Park (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b).

The dominant land use is grazing (67%, 271,000ha), followed by conservation (19%, 75,000ha). The remaining land uses are all less than 7% of the basin area. The Baffle has the least amount of cane of the all basins with approximately 5,400 ha (Fentie et al. 2014; Australian Bureau of Statistics 2014).

There is also potential for mining; mineral and silica sand mining leases and an oil-shale deposit exists at Lowmead. Various intensive production uses are also developing including aquaculture, feedlots, macadamia nut and mango production. Plantation forestry and tourism area of growth within the region (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b).

2.8.2 Burnett

The Burnett basin is by far the largest basin the in region (3,304,000ha), accounting for 63% of the total region area. The Burnett River rises in the Bunya Mountains south-west of Kingaroy, while the north-west and Bania branches rise in the Burnett and Bania forestry areas of the Perry Shire. The Burnett river system includes several smaller tributaries, including the Perry, Nogo, Boyne, Stuart and Auburn, and a number of major creeks including the Barker, Barambah and Three Moon. Three Moon Creek is the northern most element of the Burnett system and begins north of the Cania Dam in Monto Shire.

The Burnett basin has the second highest population in the region, with around 94,100 residents. The dominant land use is grazing (77%, 2,500,000ha), followed by forestry (12%, 405,000ha). There is approximately 10,100 ha of sugarcane, and the largest areas of dryland cropping (approx. 81,000ha), irrigated cropping (approx. 41,000ha) and horticulture (approx. 10,000 ha) are in the Burnett basin. It also contains several water impoundments including Paradise Dam (Australian Bureau of Statistics 2014; Fentie et al. 2014). The catchment has undergone extensive modification over the past 40 years, including industrial and port development at the river mouth.

The western area of the Burnett basin contains part of the southern portion of the Brigalow Belt which was extensively cleared through a development scheme in the late 20th century. The Brigalow Belt South has been identified as an Australian Biodiversity hotspot because of its unique species and the threats they face.

2.8.3 Kolan

The Kolan is the smallest of the five major basins (296,000ha), accounting for only 6% of the region area and a small population with only around 7000 residents. The dominant land use in the Kolan basin is grazing (~69%, 203,000ha). The remaining land uses are all less than 10% of the area, although the basin has a significant area of sugarcane (approximately 11,000ha) (Fentie et al. 2014; Australian Bureau of Statistics 2014).

The Kolan discharges to receiving waters of the Great Sandy Marine Park. The Kolan River Barrage has reduced the natural length of the estuary by about half; from around 31km to 15km. Flows in the Kolan River are highly regulated as part of the Bundaberg Irrigation Scheme, with three structures: Fred Haigh Dam, Bucca Weir and the Kolan River Barrage. A considerable proportion of the length of the Kolan River is regulated by these structures. As a consequence of extensive river regulation and water use in the catchment, even medium and high flow regimes have been significantly reduced (Burnett Mary Regional Group 2009).

2.8.4 Burrum

The Burrum basin is the second smallest catchment in the region (behind the Kolan), occupying approximately 345,000ha accounting for only 7% of the region area (Fentie et al. 2014). The Burrum basin has mixed land use profile with grazing (37%, 129,000ha), forestry (22%, 77,000ha) and conservation (21%, 72,000ha) as the dominant land uses. The Burrum basin has the greatest area of sugarcane (15,700 ha) (Australian Bureau of Statistics 2014). It also has a relatively high population (approximately 79,000 residents) as a result of significant urban areas (4.5% of the catchment) including Hervey Bay City and Burrum Heads (Fentie et al. 2014).

The Burrum basin contains large tracts of intact coastal vegetation, particularly around Woodgate, although vegetation clearing for industrial, port and urban development is encroaching on coastal wetland habitats. Hervey Bay City Council derives all its town water from the Burrum River and Beelbi Creek catchments, supplying Hervey Bay City, Toogum and Burrum Heads.

The non-tidal reaches of the Burrum have all been artificially impounded resulting in significant changes in flow regime in the upper estuary. Impacts on the lower estuary are mitigated by inflows from the Cherwell, Isis and Gregory Rivers which are relatively undeveloped (Burnett Mary Regional Group 2005a; Burnett Mary Regional Group 2005b) .

2.8.5 Mary

The Mary is the second largest catchment with the region. It is 930,000ha and accounts for 18% of the total region area. The Mary begins in the Conondale Range, near Maleny in the Sunshine Coast hinterland, and flows into the Ramsar listed Great Sandy Strait at River Heads.

The Mary Catchment has several tributary creeks including Obi Obi, Yabba, Little Yabba, Six Mile, Amamoor, Kandanga, Tinana, Deep, Munna and Wide Bay Creeks.

The dominant land use in the Mary basin is grazing (51%, 472,000ha), followed by forestry (21%, 193,000ha) and conservation (18%, 166,000ha). The remaining land uses are all less than 10% of the area. The Mary basin has the highest population (approximately 101,500 residents) and the greatest area of urban land uses (54,000ha) with the major centres of Maryborough, Maleny, Kenilworth, Cooroy, Gympie, Kilkivan, and Hervey Bay (Fentie et al. 2014). There is also approximately 9,500ha of sugarcane (Australian Bureau of Statistics 2014) and gold mining continues around Gympie (Walker & Esslemont 2008).

3 Marine and Coastal Ecosystems

The region contains important marine and coastal ecosystems including the southern section of the Great Barrier Reef World Heritage Area (the Reef) and the Great Sandy Strait Ramsar wetland (the Great Sandy Strait) and the Great Sandy Biosphere Reserve.

The major ecological assets that need to be protected are saltmarsh habitat, seagrass beds, coral reefs and mangroves and their dependent flora and fauna as well as the freshwater ecosystems in the catchment. The health of these ecosystems is critical to support human uses particularly tourism, recreation and both commercial and recreational fishing as well as fulfilling Australia's international environmental responsibilities.

Despite all the work done in the Great Barrier Reef region, there has been limited work on assessing the market and non-market values of the Reef. This is important if the costs and benefits associated with protecting values are to be discussed in a robust way and for people concerned about the environment to be involved. Using available studies and supplementing these with some assumptions, a preliminary present value of the entire Great Barrier Reef has been estimated to be in the order of approximately $26 billion. Of this, the Burnett Mary region ecosystems are estimated to be within the range of $3.1-4.3 billion. The values considered in this WQIP should be considered both conservative (fresh water ecosystems have not been included for example) and there are limited studies even on the Great Barrier Reef itself.
These trends present significant challenges for sustainability, particularly in managing the increased pressure on the natural resources while providing services and access for our community.

3.1 Great Barrier Reef

The Great Barrier Reef was declared a World Heritage Area in 1981 due to its 'outstanding universal value'. This listing recognised the Reef as being one of the most remarkable places on earth, as well as its global importance and natural worth. The Reef meets all four natural criteria for World Heritage listing (Commonwealth of Australia 2014). The values in the Burnett Mary region which support its listing have been summarised for this Plan (Coppo et al. 2014) and include:

- Large extent of seagrass meadows in both shallow and deep water areas.
- Habitat for one of the world's most important dugong populations and six of the world's seven species of marine turtle.
- Significant diversity of coral reef and island morphologies (Capricorn Bunker Group and inshore and offshore coral reefs).
- Diversity of mangroves species.
- Diversity of fish species.
- Globally important breeding colonies of resident and migratory birds and marine turtles.
- An important habitat for humpback whales on their migration.

3.2 Great Sandy Strait

The Great Sandy Strait was listed as a Wetland of International Importance under the Ramsar Convention in 1999.

The Strait is a double-ended, sand passage estuary with large tidal movement located between Fraser Island and the mainland coast. The Strait meets six of the nine criteria for Ramsar listing, the values supporting its listing are (Department of Environment and Heritage 1999):

- It is an outstanding example of a sand passage estuary with rare patterned fen features and diverse habitats including sand and mud flats, salt flats, mangroves and seagrass beds.
- Provides feeding grounds for six species of threatened marine turtle, namely the green turtle, loggerhead turtle, hawksbill turtle, flatback turtle, leatherback turtle and olive ridley turtle. Other threatened species that occur include the dugong, humpback whale, water mouse, Illidge's ant blue butterfly, and the Oxleyan pygmy perch.
- Supports at least 38 species of shorebirds, 104 species of fish, 27 species of molluscs, hard & soft coral species, 11 species of mangrove, and seven species of seagrass. The mangrove communities within the Strait represent a transition between essentially temperate and tropical species.
- Supports in excess of 20,000 migratory shorebirds. Counts between 30,000 and 40,000 shorebirds have been recorded on several occasions.
- Supports more than 1% the total world population of the following species: eastern curlews, grey-tailed tattlers, lesser sand plovers, terek sandpipers, whimbrels, bar-tailed godwits, pied oystercatchers, greenshanks and grey plovers.
- Provides important habitat and feeding grounds for juvenile and adult fish, prawns and other crustaceans. It is highly valued for commercial and recreational fishing.

3.3 Ecological Values

3.3.1 Seagrass

Seagrass is the most important marine ecosystem within the Burnett Mary region supporting populations of dugong, turtle and fisheries of commercial and recreational importance. There is a large area of seagrass to the south of the GBR Marine Park boundary, in Hervey Bay, providing important habitat and foraging grounds for large migratory fauna species that also inhabit the region. The total estimate of seagrass area in the Burnett Mary marine region (within the Reef) is 6,300km^2, while the estimated area in the broader marine region that extends south into Hervey Bay is around 9,000km^2 (Waterhouse et al. 2014).

Seven species of seagrass have been recorded across four habitat types (estuarine, deep water, coastal and reef) since the first survey of seagrasses within the Burnett Mary region was undertaken in 1973. Only five species; *Halodule uninervis, Zostera muelleri (capricorni), Halophila ovalis, Halophila spinulosa* and *Halophila decipiens* have been commonly recorded in all surveys/monitoring in the region since 1973.

Estuarine and deep water seagrass meadow habitat types are well represented, however the current condition of deep water seagrass is unknown due to a lack of monitoring. Very few coastal seagrass meadow habitat types are present due to topography of the region. There is no documented knowledge of reef seagrass meadow habitat type(s) but they are likely to persist on reef tops of Capricorn Bunker Islands.

Seasonal and annual fluctuations in seagrass abundance have been recorded and these patterns fall within larger cycles of seagrass loss and recovery. Deteriorating water quality associated with flood plumes has been strongly linked to seagrass decline in the region (Coppo et al. 2014). Recovery rates depend on many factors including species mix, reproductive ability and sediment type.

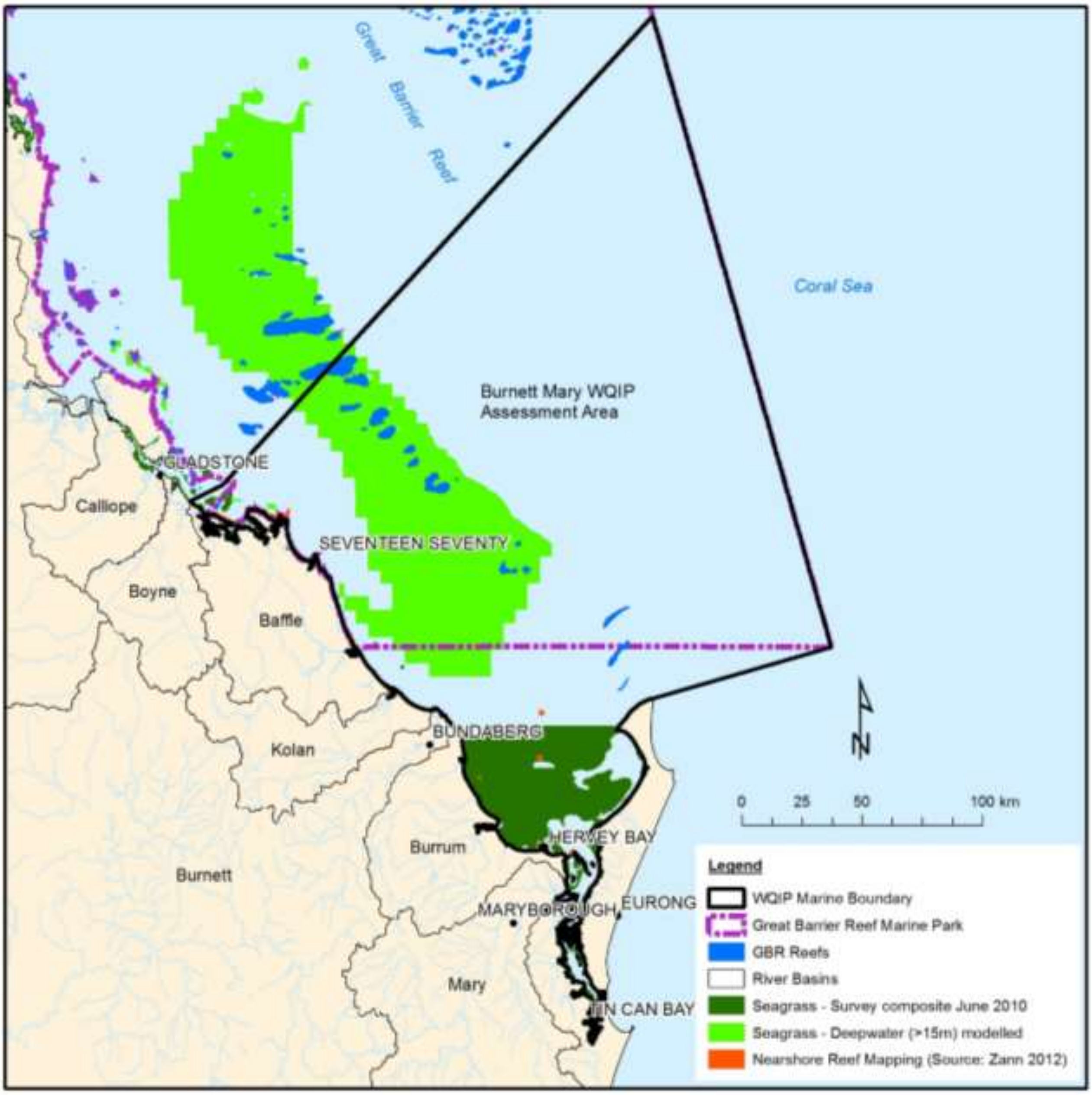


Figure 5. Locations of coral reefs and seagrass meadows (from Waterhouse et. al2014)

The seagrass meadow areas in Hervey Bay support the highest density dugong habitat south of the Torres Strait. Unfortunately they have been severely impacted by several high discharge events from the rivers systems in 1992, again in 1999, 2011 and 2013. The loss of seagrass after these floods had dramatic impacts on Dugong mortality and migration.

3.3.2 Dugong

The Hervey Bay region of the Great Sandy Strait supports between 500 and 2000 dugong and is one of the most significant dugong populations on the east coast of Australia. Dugong numbers have fluctuated over the years and this largely relates to changes in seagrass condition, with high mortality rates resulting from storm events and disturbance of seagrass.

The relative dugong density in Rodd's Bay (in the north of the region) is lower than in Hervey Bay (in the south of the region). Observations of dugong feeding trials during seagrass surveys, showed that dugongs use the Rodd's Bay seagrass meadows for feeding. These meadows stand halfway between the important dugong habitats in Shoalwater Bay and Hervey Bay. As those areas are approximately 400km apart, the Rodd's Bay region is important in maintaining the interchange of dugongs between central and south-east Queensland.

3.3.3 Turtles

Six of the world's seven sea turtle species have been recorded in the Burnett Mary region, with Mon Repos having the largest concentration of nesting marine turtles in Eastern Australia.

Green turtles are the most abundant marine turtle species on the Reef. The Capricorn Bunker group of islands, Hervey Bay and Great Sandy Strait are important foraging grounds and juvenile habitat for green turtles in Queensland. In the Burnett Mary region, the key nesting and inter-nesting areas are in the Capricorn Bunker group with an average annual nesting population estimated at 8000 females with a smaller site at Mon Repos.

The most significant loggerhead turtle nesting population in the South Pacific Ocean is located at Mon Repos and adjacent beaches of Woongarra Coast and Wreck Rock Beach. Additional nesting takes place in the Capricorn-Bunker Group of islands. Successful breeding here is critical for the survival of this endangered species.

Leatherback turtles have occasionally occurred in the Burnett Mary region at Wreck Rock, near Deepwater National Park, north of Bundaberg and adjacent beaches near Bundaberg however there is a strong likelihood that no leatherback turtles have nested in Queensland since 1996 (Coppo et al. 2014).

3.3.4 Coral Reefs

The Burnett Mary region has two geographically distinct areas of coral reefs. These are the inshore coral reefs which occur along the coastline and in Hervey Bay and the offshore reefs of the Capricorn-Bunker group and Lady Elliot Island.

The offshore reefs in the Capricorn Bunker group are located approximately 10km west of the edge of the continental shelf. The reef flat consists mainly of *Acropora spp*. Branching and massive corals are also common in the lagoon and may form patch reefs whereas the growing edges and the terrace support the branching (staghorn) varieties.

The inshore reefs are relatively healthy and an unusual example of marginal, subtropical coral reefs. They represent an important transitional area between the more tropical reefs of the north, and the sub-tropical reefs to the south. There are 102 identified coral taxa of which 78 are hermatypic hard corals, 6 ahermatypic hard corals and 18 soft corals, including gorgonians.

3.3.5 Cetacean

There are over 30 species of whale and dolphin found in the Reef and all are likely to occur in the Burnett Mary region. Important species in the Reef include: humpback whale. dwarf minke whale, snubfin dolphin, Indo-Pacific humpback dolphin and Risso's dolphin (which Fraser Island has the only known 'resident' population in Australia).

In the Hervey Bay area, southern right whales have also been sighted, although this is considered rare. Humpback whales usually stop and rest or play in Hervey Bay for several days on their southbound migration; as it is sheltered by Fraser Island. Many humpback whales return to Hervey Bay over multiple years - it is one of the ten top whale watching locations in Australia.

3.3.6 Birds

Wetlands along the Great Sandy Strait regularly support in excess of 20,000 migratory shorebirds, with counts of up to 40,000 recorded. Eighteen of the 24 migratory species listed under the JAMBA CAMBA and ROKAMBA agreements are also found. Maximum numbers recorded include grey-tailed tattler (7681), eastern curlew (6018), bar-tailed godwit (13 359), greenshank (1069) and terek sandpiper (2494).

The wetlands along the Great Sandy Strait regularly support more than 1% the total flyway (or world) population of the following species: eastern curlew (19.6%), grey-tailed tattler (16.2%), lesser sand plover(5.5%), terek sandpiper (5.0%), whimbrel (3.8%), bar-tailed godwit (3.7%), pied oystercatcher (3.2%), greenshank (2.6%) and grey plover (1.6%).

The Great Sandy Strait also supports an appreciable number of yearling eastern curlew *which* do not migrate in their first winter and are listed as Rare under the *Nature Conservation Act 1992 (Queensland).* The Great Sandy Strait is a site of international significance for this species, having the highest number of non-breeding eastern curlew being recorded here on their southern migration.

3.4 Assessing the value of the marine ecosystems

The marine ecosystems of the Burnett Mary region have important social, economic and ecological values. Tourism and recreation are particularly important uses associated with the Capricorn Bunker Islands, Hervey Bay and Mon Repos. Commercial and recreational fishing are also important uses throughout the region, and whale watching is a major tourist draw card to the Hervey Bay area.

Limited studies have been completed on the social and economic values of the Burnett Mary marine environment. As part of this WQIP, a study into the monetary values of the marine assets was completed, the results of which are included in this section.

3.4.1 Determining value of the Burnett Mary marine ecosystems

The importance of the environment can be expressed in terms of its ecological, socio-cultural, and economic values. Market values (or use values) refer to the benefits that humans realise when interacting with the environment in some way (for example Reef-specific tourism, commercial fishing and recreation), and non-market (non-use) values represent the worth that an individual or community attaches to the environment in addition to, or irrespective of their use values. The total of all market and non-market values across ecological, socio-cultural and economic dimensions of the environment is its “true” or total value (Thomas & Brodie 2014).

For this WQIP economic value has been determined by using a combination of market and non-market values. This information has then been used to generate a score to inform understanding of the relative value of the marine ecosystem of each GBR region and provide a numerical score as an input to INFFER.

Market values were based on an adjustment to the 2013 study of the contributions of the GBR to the Australian economy completed by Deloitte Access Economics (Deloitte Access Economics 2013). Non market valuation was completed by TropWater to inform this WQIP (Thomas & Brodie 2014).

On the basis of these studies, a total value of A$26 billion has been ascribed to the entire Great Barrier Reef, which corresponds to a V score of 1300 in INFFER where each unit is equal to A$20 million.

A summary of these economic valuations and a comparison between the regions of the GBR are provided in Table 3 and described below.

Table 3. Regional breakdown of total market and non-market values (A$m/yr), and associated scores of the of Great Barrier Reef

Region	Reef(marine)-specific tourism		Commercial fishing		Recreation		Non-market[1]		Average score
	A$m	Score	A$m	Score	A$m	Score	A$m	score	
Cape York	18	34	37	270	3	17	82	472	198
Wet Tropics	248	478	18	129	58	309	26	147	266
Burdekin	100	193	42	302	53	285	32	181	240
Mackay-Whitsunday	97	188	24	172	29	153	13	77	148
Fitzroy	101	195	29	212	40	215	40	232	213
Burnett-Mary	111	213	30	215	60	322	33	191	235
Total	675	1,300	180	1,300	243	1,300	227	1,300	1300

Market Values

Almost 50% of the monetary value of the Burnett-Mary has been estimated to be derived from marine tourism activities (A$111M per year). Recreational values contribute 26% (A$60M per year); commercial fishing approximately 13% (A$30M per year) and non-market values contribute approximately 14% to the total monetary value of the Burnett Mary portion of the Great Barrier Reef. The annual value of tourism expenditure exclusively attributable to whale-watching in Hervey Bay is over A$7m per year, and over one season approximately A$30M is injected into the region each year, including indirect and employment values (Thomas & Brodie 2014).

Non Market Values

The assessment of non-market values used the contribution of each region to total asset area (seagrass, coral etc.) and expressed this proportion as a function of total monetary non-market value. The Burnett Mary was assessed as having a non-market value of $33M/annum; this was based on the following:

The Burnett-Mary region comprises the fourth-largest marine and coastal ecosystem area in the Great Barrier Reef. Coral reefs in the region comprise approximately 3% (323 km^2) of the total

[1] Including seagrass and coral areas in the Great Sandy Strait.

ecosystem area; and approximately 24% of total seagrass (second only to Cape York) and 10% of total coastal wetland areas (ranked third after Cape York and Fitzroy).

Summary

Table 3 indicates that values for reef-specific tourism, commercial fishing and recreation, together with non-market values, vary in importance across the six regions of the Great Barrier Reef. The individual values for each category have been combined to produce an average score for each region. On this basis the Burnett-Mary region has been assigned a score of 235, the total of market and non-market values, as a fraction of the overall Great Barrier Reef score of 1,300.

4 Threats to marine and coastal values

Marine and coastal ecosystems in the Burnett Mary region are impacted on by a range of threats. This includes pollutants from land based runoff (containing sediment, nitrogen, phosphorus and pesticides from rural and urban sources), coastal development, shipping (and boating), fishing/netting and climate change (warming and prolonged high temperatures, shifting rainfall patterns, rising oceans and significant drying trends).

Degrading water quality through nutrient enrichment, turbidity, sedimentation and pesticides all affect the health of the Reef and the Great Sandy Strait, particularly inshore coral reefs and seagrass meadows. This in turn, affects iconic species such as dugong, cetaceans, turtles and seabirds.

Compared to pre-European conditions, the mean-annual river loads of sediment and nutrient to the Reef have increased between two and nine times. The greatest risk posed to coral reefs and seagrass from degraded water quality is from the Mary basin (for sediment, nitrogen and phosphorus), followed by the Burrum (which has the highest pesticide loads) and Burnett basins. Contributions from stream bank erosion in the Burnett basin may be under-estimated. The influence of the Kolan and Baffle basins is relatively low in comparison to the Mary, Burnett and Burrum basins. Overall the Mary basin poses by far the greatest challenge to the marine ecosystems of both the Great Sandy Strait and the Great Barrier Reef.

Catchment runoff, with the resulting pollutant loads and poor water quality, is considered to have the greatest overall impact on coastal and marine assets in the region. Coastal development directly impacts estuaries, coastal wetlands and mangroves through disturbance and removal of habitat. Iconic fauna species may also be affected by coastal development, for example due to increased boating and fishing pressure in the area and increased light in built up areas which effects marine turtles. Coastal development is considered a significant threat to estuaries, coastal wetlands and mangroves and turtles and seabirds in the Burnett Mary region.

In the future, climate change has the potential to be the most significant threat to offshore coral reefs. The extent and persistence of the impact from climate will largely depend on the rate and magnitude of change in the world's climate and on the resilience of the ecosystem itself. Declining water quality, coastal development, fishing and shipping are all potentially more able to be managed than climate change.

4.1 Water quality issues and principal causes

Declining marine water quality, influenced by catchment runoff, is recognised as one of the most significant threats to the long-term health of the Reef (Jon Brodie et al. 2013). Marine ecosystems and the catchments are part of a dynamic, interconnected system. The relationship between land use, water quality and ecosystem health indicators (e.g. coral cover and seagrass abundance) is relatively well understood for the Reef. While there has been less direct research on these matters for the Great Sandy Strait extrapolations can be made.

Nutrient enrichment, turbidity, sedimentation and pesticides all affect the health of the Reef and the Great Sandy Strait, particularly inshore coral reefs and seagrass meadows at local and regional scales (Australian Government & Queensland Government 2014). This in turn, affects the iconic species (dugong, cetaceans, turtles and seabirds) in the region.

Seagrass beds and their associated fauna (Dugong, Turtles, Fish and Birds) are extremely susceptible to inflows of sediment from terrestrial areas. This is even more so for seagrasses in the semi-enclosed areas of Hervey Bay and the Great Sandy Strait, where water exchange following high inflows can take a long time (Coppo et al. 2014). More than 1,000 km^2 of seagrass meadows were lost in Hervey Bay in February 1992 following two large floods in the Mary and Burrum Rivers. As a consequence, the population of dugongs in the area decreased from an estimated 1466 individuals in 1988 to 92 in late 1992 (Fentie et al. 2014).

There are also important areas of inshore coral reefs in the Great Sandy Strait that have been impacted by river discharge events from the Burnett Mary catchments. Finally, pesticides discharged from the Mary River in particular have been found in estuarine and marine sections of Hervey Bay at concentrations potentially able to reduce photosynthesis in seagrass (Waterhouse et al. 2014). Impacts from the more recent floods in 2012 and 2013 are still being investigated and have not yet been quantified.

Pollutants may also interact to have a combined effect that is greater than the effect of each pollutant in isolation (Coppo et al. 2014). Water quality issues have been documented in three preceding WQIPs for the Burnett Mary Region (the Burnett-Baffle, Burrum and Mary WQIPs). These WQIPs identified the following issues (Fentie et al. 2014; Burnett Mary Regional Group 2009; Walker & Esslemont 2008; Walker & Esslemont n.d.):

- Total Suspended Sediment from grazing and stream bank erosion
- Dissolved nutrients from sugarcane, horticulture and urban land uses
- Herbicides from sugarcane, horticulture and cropping land uses

4.2 Climate change

Australia has already experienced warming and prolonged high temperatures, shifting rainfall patterns, rising oceans and significant drying trends. The intensity of disturbances to the Burnett Mary marine region is set to increase under future climate change scenarios. The average annual seawater temperature on the reef is likely to rise by one to three degrees Celsius by 2100. It is also predicted that Reef waters will become more acidic, sea levels will continue to rise, patterns of ocean circulation will change and weather events will become more extreme (Australian Government & Queensland Government 2014).

Climate change will have impacts on all the marine and coastal assets and is estimated to be the most significant threat to offshore coral reefs in the Burnett Mary region (Coppo et al. 2014). The effects on offshore reefs includes increased water temperature, increased light and ultraviolet radiation, ocean acidification, sea level changes and increased frequency and severity of tropical storms and flooding events. This is also the case for inshore coral reefs however these have the additional threat of increases in terrestrial pollutants. Increases in water temperature push corals beyond their thermal tolerance and corals under thermal stress are more highly sensitive to light and ultraviolet radiation levels. Ocean acidification significantly reduces the skeleton forming capacity of corals and may impact the ability of coral reefs to ‘keep up with’ sea level rises. Increased frequency and severity of destructive storms reduces the opportunity of reef communities to recover from storm events (Coppo et al. 2014).

The extent and persistence of damage to the Reef will largely depend on the rate and magnitude of change in the world’s climate and on the resilience of the ecosystem itself. This has important implications for the future management of the Great Barrier Reef and run-off entering the reef lagoon.

4.3 Current water quality status

Excess nutrient and sediments enter the marine environment as a result of climatic events – extreme rainfall events and climate variability mean that losses of sediment and particulate nutrients can occur even in natural systems. Some of this excess occurs naturally, whilst human induced changes since European settlement (termed anthropogenic impacts) occur as a result of agricultural and urban activities. Recent pollutant load estimates confirm that water discharged from adjacent catchments to the Reef continues to be of poor quality in many locations. Compared to pre-European conditions mean-annual river loads to the Reef have increased between three and five times for total suspended solids, two and six times for nitrogen and two and nine times for phosphorus (Kroon et al. 2013).

Source Catchment modelling from the Paddock to Reef program provides a prediction of end of catchment loads for key pollutants of interest (nitrogen, phosphorus, sediment and pesticides). The variables modelled include: Total Suspended Solids (TSS), Dissolved Inorganic Nitrogen (DIN), PSII Herbicides (PSII), Particulate Nitrogen (PN), Particulate Phosphorus (PP) and Dissolved Inorganic Phosphorus (DIP).

The 2008-09 baseline results from the Source Catchments modelling have been analysed to provide a summary of the relative contribution from the five river basins as a proportion of total load and anthropogenic load (Waterhouse et al. 2014).

4.3.1 Total Suspended Solids (TSS)

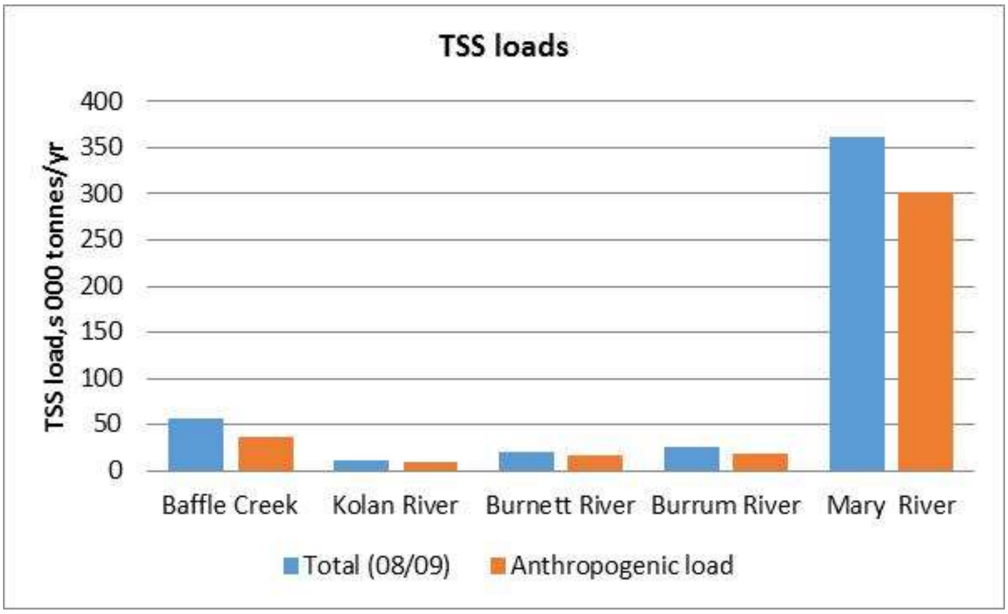


Figure 6. Annual load estimates for TSS from the basins in the Burnett Mary region (thousands of tonnes).

The Mary basin is estimated to contribute the greatest total and anthropogenic TSS loads in the region, estimated at 362,000 tonnes and 301,000 tonnes per year respectively (see Figure 6). The anthropogenic contribution accounts for 63% of the total regional load. Basins other than the Mary contribute are estimated to contribute less than 10% of the total load. The lowest contribution is from the Kolan River (<2%). In comparison to all other Reef basins, the Mary is the fourth largest contributor of TSS to the total Reef TSS load, however, the Burnett Mary overall contributes around 5% of the total Reef TSS load.

Flooding in the Burnett River in 2013 has exacerbated concerns in the region about sediment being delivered to downstream locations including dams/weirs and ultimately the Reef.

A stability assessment was commissioned following these events to; inform planning of flood recovery works; improve understanding of the system wide stability and understand the relative contributions of bank sediment particularly fine grained material to overall sediment loads (Simon 2014).

Initial findings for the Burnett revealed that bank erosion was a more significant source of sediment than had previously been estimated. Bank erosion, instead of being a minor source of sediment representing 8% of the total, was found to be the single largest contributor of sediment in the Burnett River catchment, representing at least 44% of the total, annual sediment budget. In absolute terms, this is an increase in the previously reported average, annual rate of bank erosion from 0.175 Mt/yr. to 2.0 Mt/yr. (Simon 2014).

This has implications for this WQIP because it is possible that the modelled contributions of stream sediment are significantly underrepresented. If this proves correct this could have major impacts on the selection of management activities and practices through the bioeconomic model which underpins this WQIP. The results from the Burnett study require further analysis and discussion. The conceptualisation of stream bank and erosion processes in Source Catchment is very simple currently. As Source Catchments is the basis of quantifying and partitioning between contributions from hill slope, gully and stream bank erosion, it is important to reconcile and understand the major differences between the findings of Simon (Simon 2014) and modelled outputs.

4.3.2 Dissolved Inorganic Nitrogen (DIN)

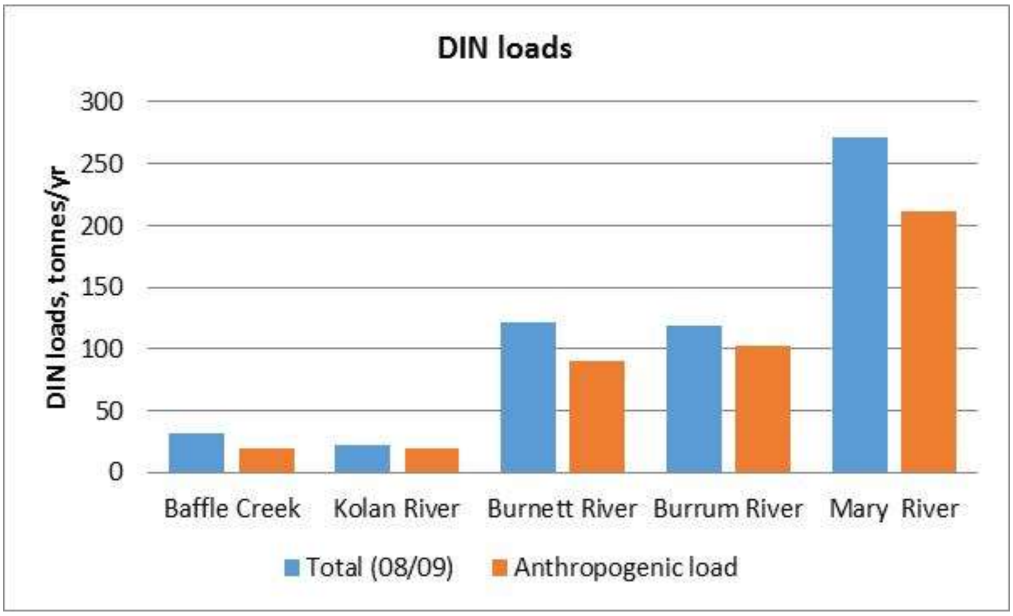


Figure 7. Annual load estimates for DIN from the basins in the Burnett Mary region

The Mary basin is also estimated to contribute the greatest total and anthropogenic DIN loads in the region, estimated at 271 tonnes and 211 tonnes per year respectively. The anthropogenic contribution accounts for approximately 37% of the total regional load. The Burnett (16%) and

Burrum (18%) basins contribute almost half the load of the Mary, whereas the Baffle and Kolan basins contribute minor loads (~3%). In comparison to other Reef regions, the total DIN load from the Burnett Mary region is estimated to be relatively low (~5%).

4.3.3 PSII Herbicides

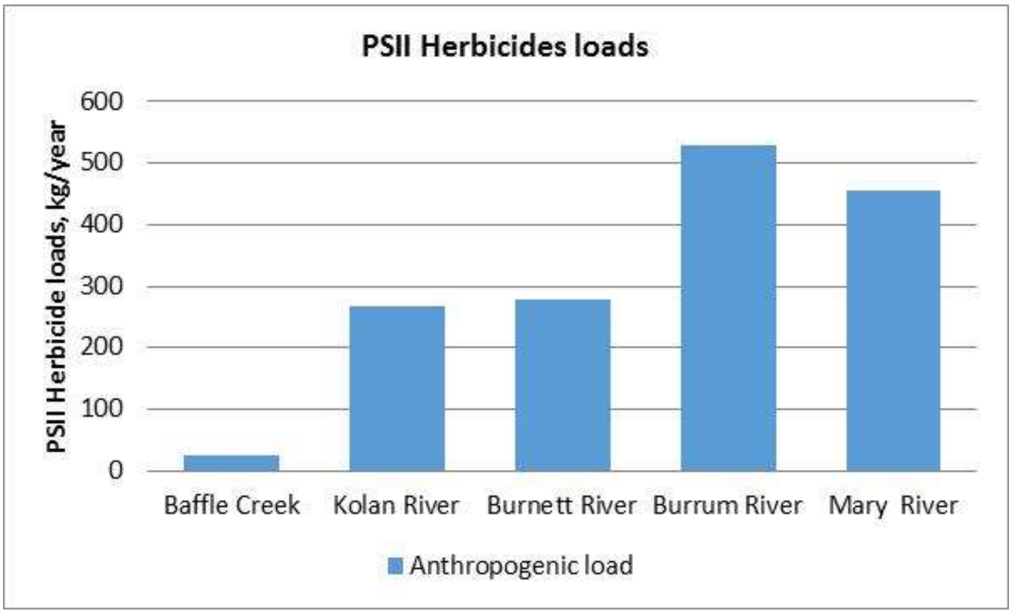


Figure 8. Annual load estimates for PSII herbicides from the basins in the Burnett Mary region.

The Burrum basin contributes the greatest PSII herbicide loads in the region, estimated at 530 kilograms per year (note that the total load is equal to the anthropogenic load; no pesticides are present in non-agricultural systems). This accounts for approximately 34% of the regional load. The Mary basin is the next highest contributor (30% total load), followed by the Burnett and Kolan. The Baffle only contributes a minor load (approximately 2%) due to the small amount of sugarcane land use. In comparison to other regions of the Reef, the PSII loads are relatively low (around 10%).

4.3.4 Particulate Nitrogen (PN)

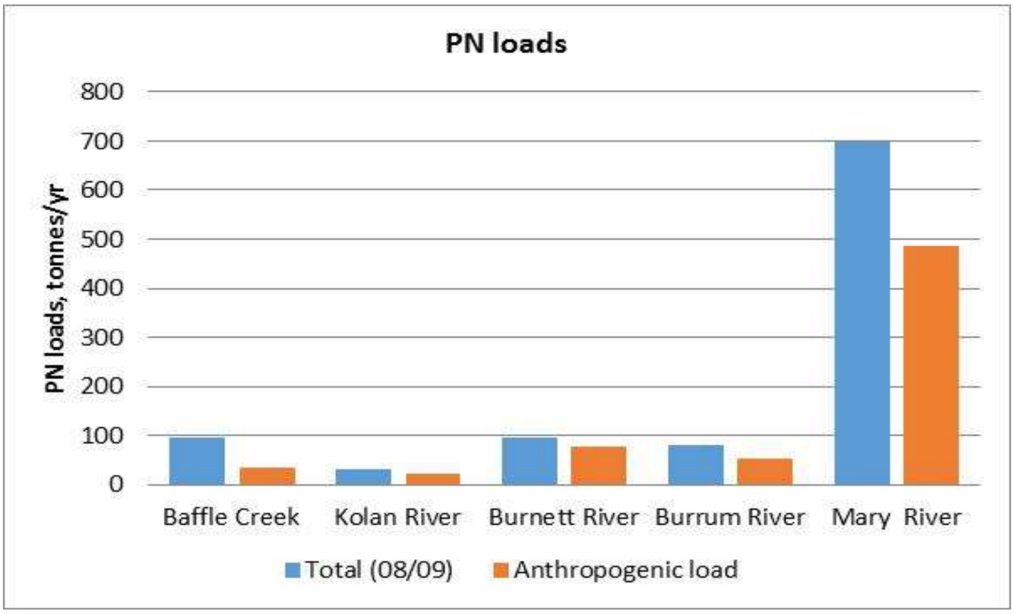


Figure 9. Annual load estimates of Particulate Nitrogen from the basins of the Burnett Mary region

The Mary basin is estimated to contribute the greatest total and anthropogenic PN loads in the region estimated at 697 tonnes and 487 tonnes per year respectively, with particulate nutrient losses being highly linked to TSS. The anthropogenic contribution accounts for approximately 49% of the total regional load. All other basins only contribute a small proportion to the regional anthropogenic load. In comparison to other regions of the Reef, the total PN load from the region is relatively low (approximately 8%).

4.3.5 Dissolved Inorganic Phosphorus (DIP)

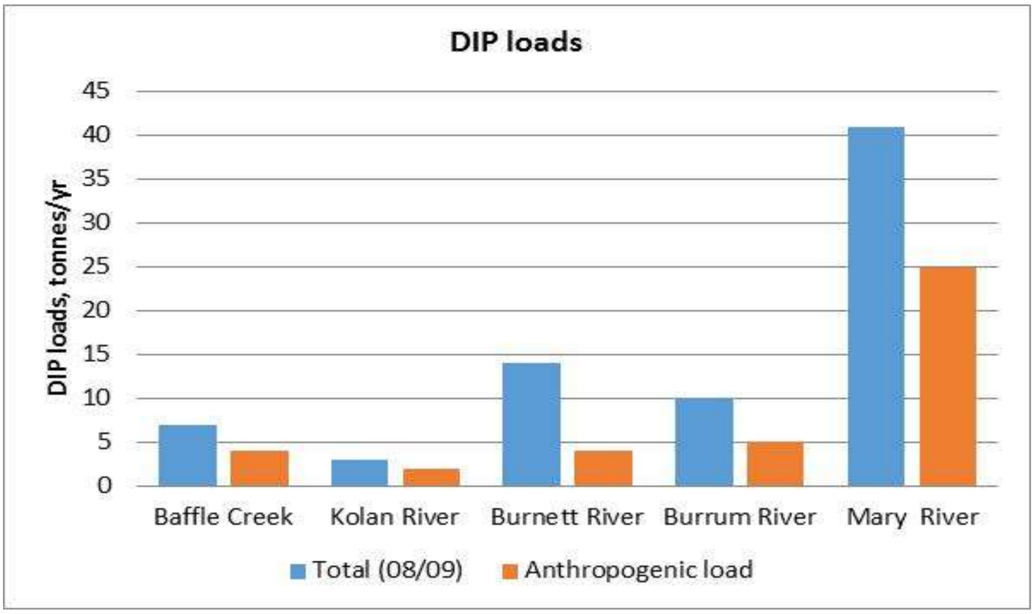


Figure 10. Annual load estimates for Dissolved Inorganic Phosphorus from the basins in the Burnett Mary region

The Mary basin is estimated to contribute the greatest total and anthropogenic DIP loads in the region, estimated at 41 tonnes and 25 tonnes per year respectively, accounting for approximately 49% of the total regional load. All other basins contribute a small proportion. Overall the total DIP load from the region is relatively low (approximately 6%) compared with other Reef regions.

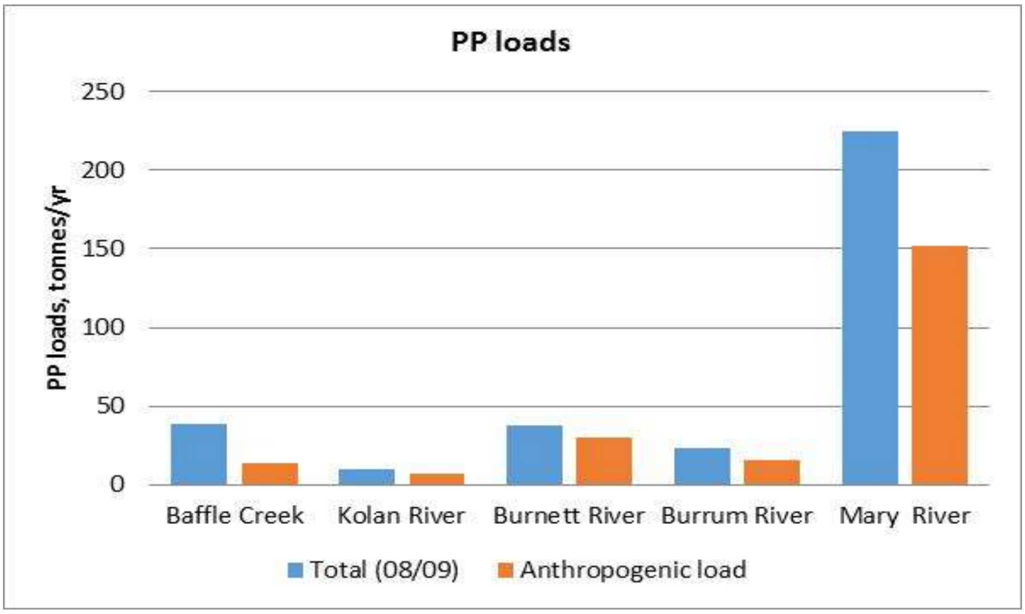


Figure 11. Annual load estimates of Particulate Phosphorus from the river basins of the Burnett Mary region

4.3.6 Particulate Phosphorus

Because of the link between sediment and phosphorus, the Mary basin also contributes the greatest total and anthropogenic PP loads, estimated at 225 tonnes and 152 tonnes per year respectively, accounting for approximately 45% of the total regional load (Fentie et al. 2014). In comparison all other basins contribute a small proportion to the regional anthropogenic load. Again, in comparison to other NRM regions in the Reef catchment, the total PP load from the region is relatively low (~11%).

4.4 Water quality risk assessment

Figure 12. MODIS Aqua image showing the influence of river discharge on the marine environment (from Waterhouse et. al 2014)

A preliminary assessment of the relative risk of degraded water quality to the marine ecosystems of the Burnett Mary was completed as a supporting project to the WQIP (Waterhouse et al. 2014). The project extended a water quality risk assessment from the Reef into the coastal and marine areas of the region. The relative risk of degraded water quality among the five Burnett-Mary basins was assessed by combining information on the estimated ecological risk of degraded water quality to coral reefs and seagrass meadows in receiving waters with end-of-basin pollutant loads. The preliminary risk assessment results have been used together with the bioeconomic modelling and Benefit:Cost analysis to prioritise the five river basins within the Implementation Plan.

Two indexes were developed, a Marine Risk Index and a Pollutant Loads Index. For assessment of the marine risk, a suite of water quality variables were chosen that represents the pollutants of greatest concern with regards to agricultural runoff and potential impacts on coral reef and seagrass ecosystems. Pollutant load estimates were combined into a Loads Index which is based on the anthropogenic proportion of the regional load for each basin and pollutant. An example of the imagery used to inform the risk assessment is set out in Figure 12. Both methods are described by Waterhouse *et al*. (2014) (Waterhouse et al. 2014).

The information was then combined in a qualitative way to make conclusions about the relative risk of degraded water quality to coral reefs and seagrass meadows among the five basins. Waterhouse *et al*. (2014) conclude that the greatest risk posed to coral reefs and seagrass from degraded water quality is from the Mary basin, followed by the Burrum and Burnett basins. The influence of the Kolan and Baffle basins is relatively low in comparison.

Overall these results indicate that the Mary region poses by far the greatest challenge to the marine ecosystems in the region. That the Mary region is outside the Great Barrier Reef Marine Park undersells the risks posed to the GBR by only including basins in the Marine Park area, as has previously occurred.

5 Approach and integration

The Burnett Mary WQIP has been developed by bringing together information from previous projects, drawing on knowledge of technical experts and local stakeholders and the completion of new studies.

These studies included the development of water quality targets, financial economic analysis of management practices on cane and grazing land and development of a bioeconomic model.

The bioeconomic model integrated paddock and catchment scale modelling results with the financial economic analysis, enabling assessment of the financial implications of meeting water quality targets.

Due to more limited information assessment of the costs of addressing water quality issues in urban areas or on horticultural land was not able to be included. The Investment Framework for Environmental Resources (INFFER) was used to assessment of the benefits and costs of achieving specified water quality targets and management scenarios.

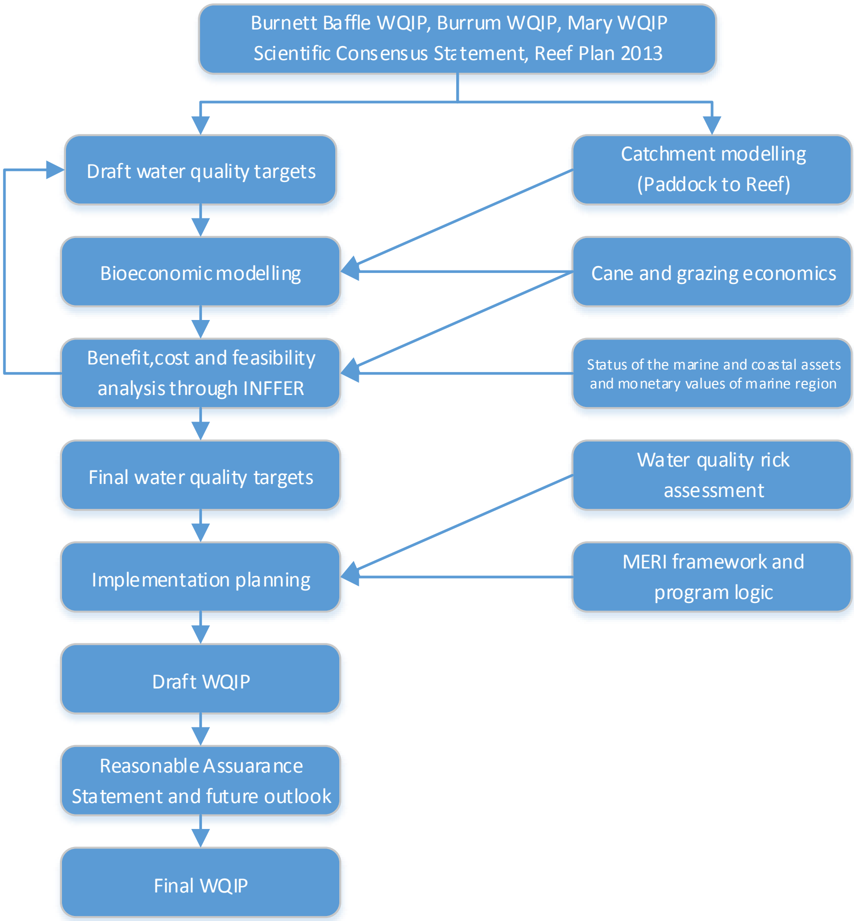


Figure 13 Key steps in developing the WQIP and linkages between components

The development of the Burnett Mary WQIP has involved integrating the outputs from a number of separate supporting projects. The approach has built on the outcomes from previous WQIPs, findings of the Scientific Consensus Statement and priorities from Reef Plan 2013 (Secretariat Reef Water Quality Plan Protection 2013; Kroon et al. 2013; Schaffelke et al. 2013; Jon Brodie et al. 2013) and new supporting studies. The key components of this approach have been:

- Coordination and engagement with technical experts and local stakeholders and integration of local knowledge and previous research
- Financial economic analysis of practices for grazing and sugar cane industries
- Development and application of a bioeconomic modelling framework to assess costs in attaining targets
- Benefit: cost analysis (INFFER) to inform implementation planning, including quantifying values.

The approach for each of these components is outlined below and the linkages between components are shown in Figure 13, followed by an overview of how each component was assessed.

5.1 Economics of sugar cane and grazing

Understanding the likely level of net benefits associated with management practice change for the sugarcane and grazing industries were key inputs to bioeconomic modelling and INFFER™. Two separate studies were undertaken in the development of this WQIP, the first involved an economic analysis of sugar cane farming systems (van Grieken et al. 2014), while the second focused on the economics of grazing systems (Pannell, Roberts, & Park, 2014). The economic analysis for both sugarcane and grazing incorporated local knowledge and a simple assessment of non-financial barriers in assessing the attractiveness (assessed as annual equivalent benefits or AEB) of practice adoption. Details of the approach are outlined in the reports mentioned above, and briefly summarised below. Results are outlined in Section 8.

5.1.1 Sugar Cane

A summary of the main steps for the sugar cane financial economic analysis for the WQIP is summarised below with full details available (van Grieken et al. 2014),

- Use of previous analyses undertaken in regions where more detailed work had been undertaken (Wet Tropics, Burdekin Dry Tropics and Mackay Whitsundays) using the ABCD framework.
- Regional input and local participation to ensure that practices had been interpreted, farm size and soil types had been captured and to collect input on practice costs (upfront and maintenance) and ranking of non-financial practice barriers.
- Productivity analysis using APSIM modelling (Keating et al. 2003)(http://www.apsim.info) on two soil types (well drained and less well drained).
- Financial economic analysis using the Farm Economic Analysis Tool (Cameron 2005).
- Quantification of non-profit barriers information.
- Investment analysis using the net present value (NPV) and annualised equivalent benefit (AEB) technique to determine if the investment is worthwhile.
- Adjustment to AEBs based on non-profit barriers.

Cane economic analysis covered AEBs associated with ABCD practice shifts (individual practices in each class were grouped) on three farm sizes (small, 75 ha; medium 125 ha; large 250 ha) covering two soil types (well drained and less well drained). The farm sizes and soil types were suggested by industry representatives.

5.1.2 Grazing

Compared with other regions in the Reef catchment, there has been limited financial-economic analysis undertaken for the grazing industry in the Burnett Mary region. A preliminary analysis was completed for the WQIP and a summary of the approach is presented below, with full details available (Pannell et al., 2014):

- Review of relevant economic analysis from other Reef regions.
- Use of the adapted ABCD framework as the basis for assessing the ability of land management practices to impact on water quality.
- Use of land condition and high-level action practices from the Reef Plan 3 (Queensland Government 2013b) to assess ABCD management practice framework.
- Local participation to ensure that practices had been interpreted, farm size and soil types had been captured and to collect input on practice costs (upfront and maintenance) and ranking of non-financial practice barriers.
- Assessment of initial land condition ascribed to the average farm.
- Assessment of the average profitability for a typical beef production system (medium productivity) using local extension expertise and adjustments to account for low and high productivity land classes.
- Incorporation of non-financial adoption aspects.

The grazing analysis covered practice shifts associated with individual practices in the ABCD framework on three land productivity classes (low, medium and high[1]) on three farm sizes (small 288ha; medium 880 ha; large 4143 ha).

5.2 Bioeconomic Modelling

Bioeconomic models can be a valuable decision support tool to support integrated environmental assessment and decision-making processes. The term bioeconomic model is typically used to describe models that have both economic and biophysical components (Roberts et al; 2014). A comprehensive bioeconomic model was developed to inform and assess the effectiveness and costs of management actions to achieve the water quality targets of multiple constituents (outlined in Section 6). The model integrated information on costs associated with practice shifts in cane and grazing industries, together with biophysical information from available catchment and paddock-scale modelling. It is the first time in Queensland such an integrated approach has been undertaken as part of the WQIP process.

Catchment modelling results from Paddock to Reef (Source Catchment) were used as the basis of assessing the possible reductions in pollutant loads, with the economic analysis outlined above used to assess the financial implications (net annual profit or costs) of achieving targets. The model has largely drawn on the assumptions from the Paddock to Reef program regarding the effectiveness of ABCD management practices for cane and grazing. As knowledge improves further, it is likely that

[1] The three land productivity classes were as per Whish G. (2012) *GRASP modelling of grazing systems in Great Barrier Reef catchments*. Technical Report to Paddock to Reef Integrated Monitoring, Modelling and reporting program funded through the Australian Government's Caring for Our Country Reef Rescue. Department of Agriculture, Fisheries and Forestry, Queensland, Australia

some of these assumptions will change, and this could have important impacts on the costs and management actions to achieve water quality targets.

Assessment of management options for urban areas was not included in the modelling due to data limitations. The urban component of the available catchment model was not suitable to be used and there is also insufficient information on both costs of management options and the area of urban land to which changed management could be applied. Once such information is better developed, urban impacts could potentially be considered as part of a bioeconomic model.

For grazing and cane, once the model was developed, different scenarios were evaluated to inform the WQIP. The scenarios assessed included; different levels of pollutant load reduction, targeting particular industries, particular basins or targets which could be achieved with particular budgets.

The model proved a powerful and transparent approach to deciding which targets would form the basis of the WQIP. Details of the modelling are provided in the reports for the supporting studies of the WQIP(Beverly et al. 2015; Roberts et al. 2014).

5.3 Benefit:Cost analysis using INFFER

INFFER (Investment Framework for Environmental Resources, (Pannell et al. 2012) was used to assess the relative cost-effectiveness for each scenario was based on the logic of Benefit:Cost Analysis (Boardman et al. 2010). Undertaking the analysis required 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, in this case the water quality targets.
- 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 risk that, despite new public investment, private landholders will adopt new works and actions that would further degrade the environmental asset.
- Legal approvals required to undertake the works and actions.
- The policy mechanisms/delivery mechanisms to be used to encourage and facilitate uptake of the required works and actions.
- Socio-political risks.
- Costs of the current project.
- Annual maintenance costs required to maintain benefits after the current project is complete.

- The risk of not obtaining those essential maintenance costs, such that project benefits are lost.

Completion of the INFFER assessment involved integrating the outputs from the bioeconomic model outline above with the supporting studies including an assessment of the monetary values and status of the marine and coastal assets (Thomas & Brodie 2014; Coppo et al. 2014), and expert knowledge of the value of the asset and the likely impact of the proposed works (i.e. the implementation of best management practices) on the asset. This information was collected through; literature review and two workshops with the WQIP Technical Panel and a follow up review period.

6 Water quality targets and program logic

Two sets of targets were considered in this WQIP, the current Reef Plan targets (RPTs) which are formally endorsed by the Australian and Queensland governments, and newly developed Ecologically Relevant targets (ERTs) which have been developed in light of recent science. Constituents considered in both sets of targets were the anthropogenic components of suspended sediments, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), particulate nitrogen and phosphorus (PN and PP) and PSII pesticides.

Both RPTs and ERTs were evaluated on the basis of either meeting targets on an individual basin (Baffle, Burnett, Kolan, Burrum, Mary) or whole of region scale. Solutions (cost and management associated with each scenario) were optimised to achieve the water quality targets for the least net cost (or greatest net profit).

Central to the Program Logic for the WQIP is a focus on reducing pollutant loads to the marine environment in order to maintain and improve the condition of seagrass and coral communities using 'SMART' targets (Specific, Measurable, Attainable, Realistic and Time-bound). SMART targets were used as the basis for linking and quantifying the actions required to achieve anthropogenic loads reductions, using the available science and knowledge base to develop a sound, costed basis for implementation (subject to available funding).

6.1 Reef Plan targets - apportioned to Burnett Mary

Reef Plan's long term goal is to ensure that by 2020 the quality of water entering the Reef from broad scale land use has no detrimental impact on the health and resilience of the Great Barrier Reef (Secretariat Reef Water Quality Plan Protection 2013).

The original Reef Plan targets were set in 2009. Since then, scientific knowledge and monitoring and modelling information has advanced significantly. As a result, the targets were refined as part of Reef Plan 2013. There is still, however, a gap in knowledge about the load reductions for specific pollutants will be required to maintain reef health and achieve the Great Barrier Reef Marine Park Authority marine water quality guidelines at a reef-wide scale (Great Barrier Reef Marine Park Authority 2010).

The Reef Plan 2013 targets have been set for the period 2013-2018 (although in reality practice change in this 5 year time period is unlikely to be feasible[1]) generally based on the reductions that are estimated to be achieved through delivery of best management practice systems. The exception is the nitrogen target (DIN in particular), which remains ambitious and may not be achievable using current best practice in some of the Great Barrier Reef Regions (Secretariat Reef Water Quality Plan Protection 2013).

For this WQIP Reef Plan targets (RPTs) were re-defined and apportioned at the individual basin scale, based on a mixed 2009 and 2013 target set (Brodie & Lewis 2014).

The RPTs for the WQIP are:

[1] *feasible* in this context means that it is must be technically possible given the assumptions that underpin the assessment of the target (timeframe is the factor in this case that is causing the target to be not feasible).

- 20% overall reduction in anthropogenic suspended sediment load
- 20% (based on Reef Plan 2013 target) in anthropogenic loads of particulate nitrogen (PN) and particulate phosphorus (PP)
- 50% (based on Reef Plan 2013) reduction in anthropogenic loads of dissolved inorganic nitrogen (DIN)
- 50% (based on 'interpreted' Reef Plan 2009) reduction in anthropogenic loads of dissolved inorganic phosphorus (DIP)
- 60% (Reef Plan 2013) reductions of loads of PSII herbicides (i.e. 2013 target). The PSII herbicides being the sum of hexazinone, ametryn, atrazine, diuron and tebuthiuron.

An important issue is that RPTs had not been set with a mechanism (bioeconomic model) to enable consideration of effectiveness of different best practice management strategies of individual constituents, nor combined effect of constituents. Construction of the bioeconomic model enables many target scenarios to be evaluated and thus can inform more realistic and feasible targets. As a result, the bioeconomic model suggests that a 50% reduction in DIP is not feasible based on Paddock to Reef assumptions using and limiting the analysis to only include practice management changes. For the WQIP this constituent was limited to a 20% reduction so as to enable feasible options and cost assessment for all other constituents.

Costs associated with achieving targets (reported in Section 8) were assumed as average annual costs for a 20 year period; thus for the WQIP the RPTs were used but practice change was assumed to occur over a more realistic timeframe than 2018.

6.2 Ecologically based targets

At the time of Reef Plan, Ecologically Relevant Targets (ERTs) had not been developed. More recent work (Brodie & Lewis 2014) enabled us to also assess costs and management implications of ERTs. In contrast to RPTs, the development of ERTs better acknowledges the lag time between reducing pollutant loads and a subsequent ecological response of significant assets affected by water quality.

The ERTs considered in the WQIP are (based on reductions in anthropogenic load from the 2008-09 baseline): 20% overall reduction in suspended sediment load; a 50% reduction in particulate nitrogen (PN) and particulate phosphorus (PP); 50% reduction in dissolved inorganic nitrogen (DIN); 50% reduction in anthropogenic loads of dissolved inorganic phosphorus (DIP) and 60% reduction of loads of PSII herbicides. Again the 50% reduction in DIP proved to be not feasible in the bioeconomic modelling analysis and this constituent was limited to a 20% reduction in scenario testing. For the bioeconomic modelling a 20 year time frame was again assumed to enable consistency between comparisons of costs to achieve RPTS and ERTs.

6.3 Implementation Targets for this WQIP

As outlined previously the development of this WQIP has been underpinned by the development and application of a purpose built bioeconomic model to a range of scenarios for water quality targets in the Burnett-Mary region. The bioeconomic model provided the ability to run many scenarios (Beverly et al. 2014), to help decide the basis for the WQIP Implementation Plan.

The following scenarios were assessed in the bioeconomic model over a 20 year timeframe to inform the implementation plan for the WQIP:

Table 4. Load reductions targets by constituent

<table>
<tr><th rowspan="3">Scenario</th><th colspan="6">Load Reduction Target by constituent</th></tr>
<tr><th colspan="5">(% Anthropogenic Load)</th><th>(% Total load)</th></tr>
<tr><th>TSS</th><th>PN</th><th>PP</th><th>DIN</th><th>DIP</th><th>PS II Herbicides</th></tr>
<tr><td>1. Reef Plan Targets (to be met in each basin)</td><td rowspan="2">20%</td><td rowspan="2">20%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">20%</td><td rowspan="2">60%</td></tr>
<tr><td>2. Reef Plan Targets (to be met across the region, with different targets attained in each basin)</td></tr>
<tr><td>3. Ecologically Relevant Targets (to be met in each basin)</td><td rowspan="2">20%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">20%</td><td rowspan="2">60%</td></tr>
<tr><td>4. Ecologically Relevant (to be met across the region, with different targets attained in each basin)</td></tr>
</table>

Note:

- Targets are based on a reduction of the anthropogenic load from the 2008/2009 baseline
- While a notional target of a 50% reduction in anthropogenic DIP was set for both RPTs and ERTs, this proved not feasible with an upper limit of slightly more than 20%. For this reason the DIP target was constrained in the model to a 20% reduction.

Both RPTs and ERTs were evaluated on the basis of either meeting targets on an individual basin (Baffle, Burnett, Kolan, Burrum, Mary) or whole of region scale. Solutions (cost and management associated with each scenario) were optimised to achieve all water quality targets for the least net cost (or greatest net profit).

Scenarios that required targets to be met on an individual basin basis were predicted to be more expensive and sometimes not feasible (particularly in the Mary basin). This is largely because of the large sediment loads generated in the Mary from stream bank erosion and the associated high costs of addressing the issue. The implication is that meeting the targets at the whole of region scale provide a more sensible basis for the WQIP than scenarios where there is an attempt to meet the targets in each individual basin. The whole of region RPTs have therefore been used as the basis of the WQIP Implementation Plan.

As discussed in detail in Section 9, whole of region ERTs would have most long term potential to protect the marine environment of the Burnett Mary region, albeit at a much greater cost than currently available budgets.

6.4 Program logic linking water quality and protecting values

The Program Logic for the WQIP was developed to summarise the outputs from the prioritisation and benefit cost analysis to describe what is required to achieve the agreed implementation water quality targets for the Burnett Mary Region. A simple Program Logic is shown in Figure 14 .

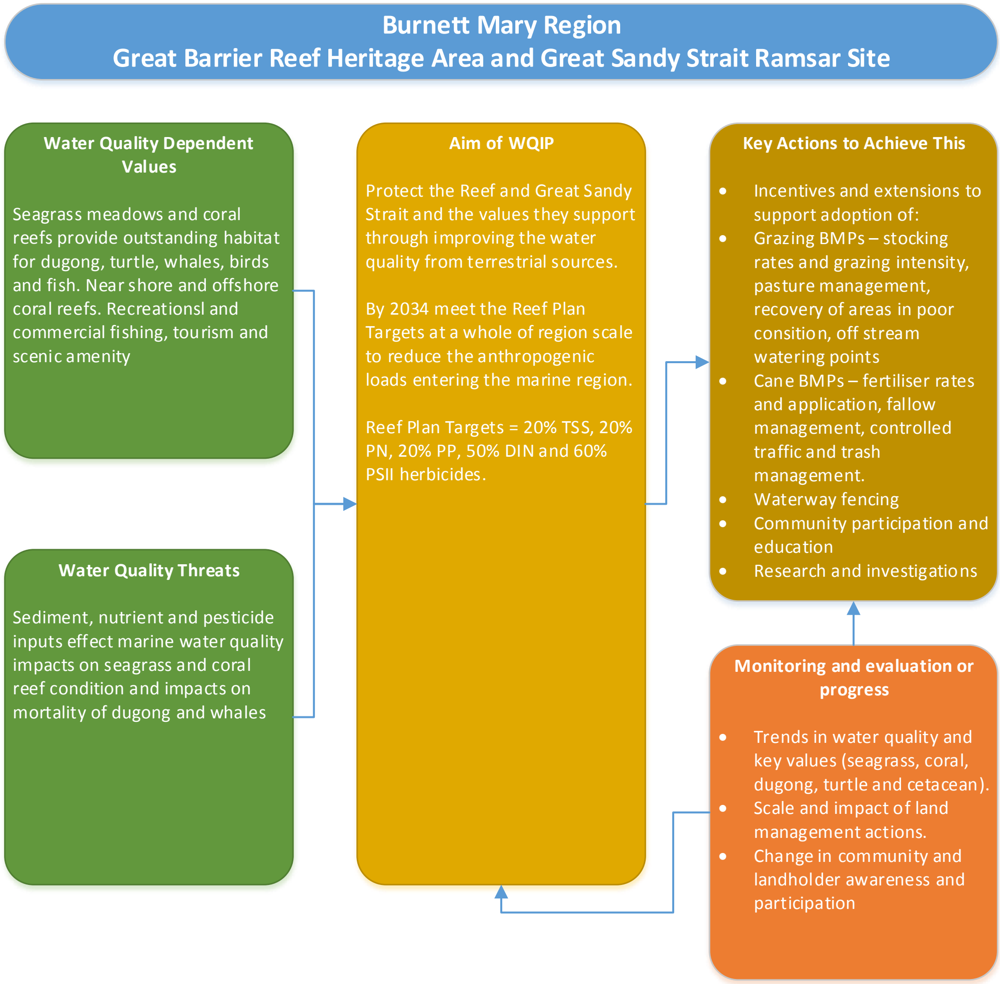


Figure 14 Simple Program Logic for the Burnet Mary WQIP

Achieving the overall aim of the WQIP requires a measurable reduction in the anthropogenic loads of nutrients (nitrogen and phosphorus), and suspended sediment and pesticides entering the marine environment from the surrounding catchments.

Elevated loads of nutrients, sediment and pesticides are likely to adversely affect the extent and condition of seagrass and coral communities in the Great Barrier Reef and Great Sandy Strait with subsequent flow-on consequences for key values including dugong, turtle and significant fish and bird populations.

Given all these factors, central to the Program Logic for the Burnett Mary WQIP is a focus on reducing pollutant loads to the marine environment in order to maintain and improve the condition of seagrass and coral communities.

The water quality targets have been based on 'SMART' principles; ones that are Specific, Measurable, Attainable, Realistic and Time-bound.

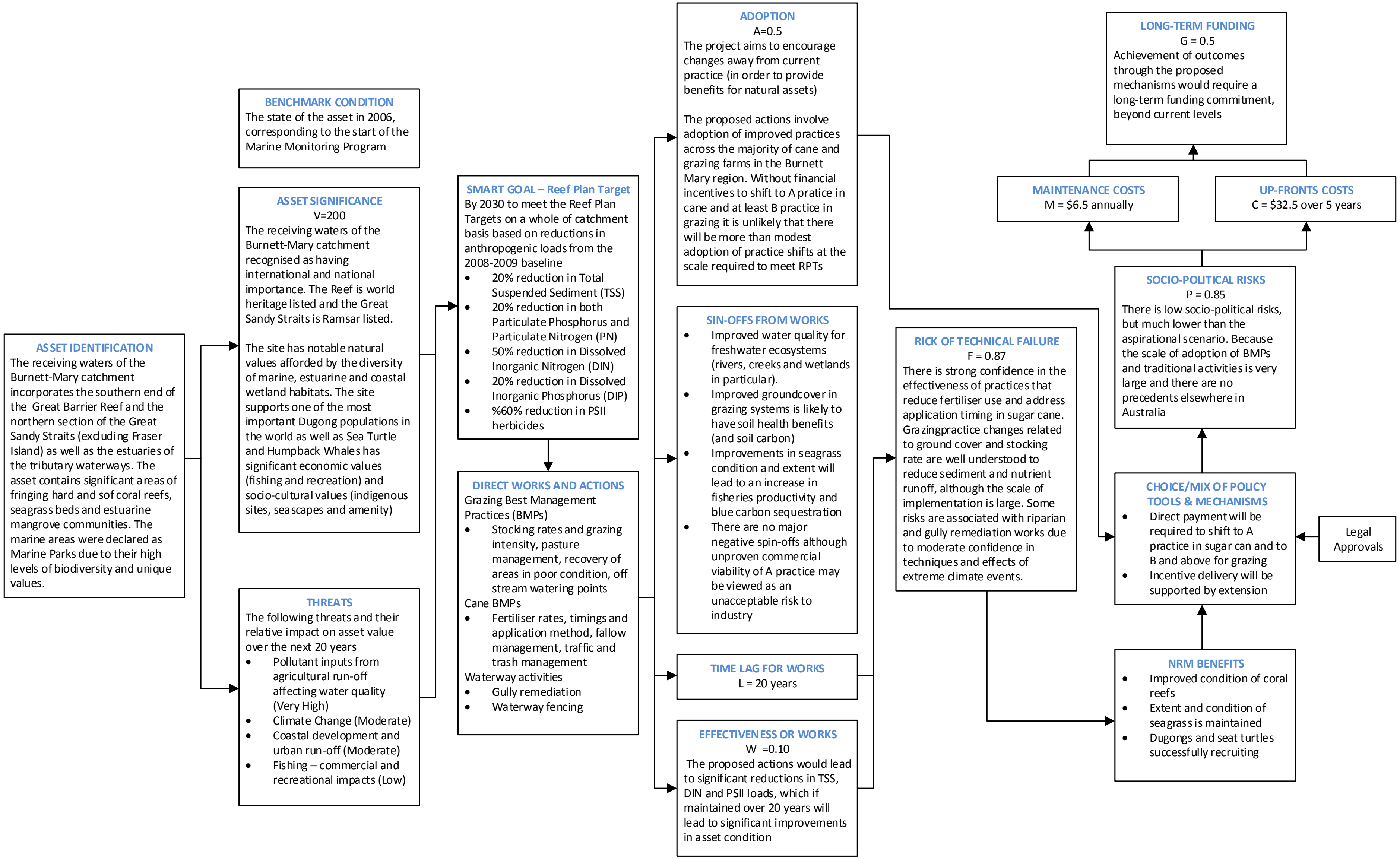
SMART targets are required as a basis for linking and quantifying the actions required to achieve anthropogenic loads reductions in the basins of the Burnett Mary region.

The assessment of the targets using bioeconomic modelling and INFFER supported an understanding of the scale of works and actions required. It also required clear definition assumptions about the effectiveness (technical feasibility) of proposed actions (Best Management Practices, waterway and erosion fencing activities). The scale of works required to meet these targets is significant (well beyond that currently) and will require large-scale adoption across the land use areas examined. Because of the scale of adoption required to achieve outcomes, the WQIP is based on payments needing to be made to farmers to recognise lost opportunity costs to production to offset the profit losses resulting from practice implementation at a scale beyond that of early farm adopters. The INFFER analysis identified the appropriate mix of policy tools required and ensured that the best estimate of costs to achieve specified water quality targets and protect the values of the Burnett Mary marine environment was made.

6.5 The link between values, water quality objectives and program logic

As outlined earlier, central to the Program Logic is a focus on reducing pollutant delivery to the marine areas of the Burnett Mary region, in order to improve the condition of seagrass communities. The SMART objectives and the available underpinning science and knowledge base provide the basis for developing a sound, costed project for the WQIP.

Using currently available science, economic analysis and local knowledge INFFER was used to assess how to achieve objectives that aim to protect the values of the Burnett Mary portion of the Reef from further deterioration due to sediment and nutrient loads, primarily from agricultural land use. In addition to the simple Program Logic diagram, a more detailed version (Figure 15) sets out the links between the values and objectives, along with all of the other important factors, which need to be considered in the development of a robust project. Unlike many Program Logic approaches where the causal links are loose and unquantified, the relationships between various factors in INFFER are explicit and quantified where appropriate.



Documentation and assessment of knowledge gaps : There is an assumption that reducing sediment and nutrient loads will result in an improvement in the ecological condition of key asset components. The basis for this assumption is moderate. There is a need to better account for spatial heterogeneity within the catchment, linkages between paddock and catchment scale models and predicted load reductions. Impact of climate change on asset values and long term ecological responses is not well understood, but believed to be significant. Information on the relationships between cane and grazing economics with adoption of improved practices (especially A class) should be a focus of future investigation.

Figure 15 Detailed Program Logic based on the INFFER analysis

7 Addressing water quality by reducing land use impacts

Paddock to Reef modelling (Source Catchment) was used as the basis of assessing land use loads and potential for pollutant load reductions. The major contributions to pollutant loads come from agricultural land uses (grazing, sugarcane, horticulture and cropping), stream bank erosion, and urban areas.

Stream banks and grazing are the dominant contributors of total suspended sediments, with most exported from the Mary and the Baffle basins. Hill slope erosion is the dominant contributor to TSS export in the Baffle, Kolan, Burrum and Burnett basins, although recent work suggests that stream bank erosion may be grossly under-estimated in the Burnett. Urban development, although a small contributor overall can be a locally high impact source, particularly during the development phase. Particulate nitrogen and phosphorus losses reflect the sediment loss patterns.

Dissolved inorganic nitrogen (DIN) loss occurs largely from fertiliser application to intensive land uses, such as sugarcane, horticulture and dairying. About 83% of the anthropogenic DIN load is predicted to come from sugarcane. DIN loss from grazing and nature conservation lands is low, given the lack of fertiliser application. Dissolved inorganic phosphorus (DIP) has received less attention than DIN and deserves more so in future; current modelling assumptions suggest that meeting current DIP targets is infeasible.

Sugarcane contributes about 31% of the PSII export load, with the majority (approximately 57%) predicted to come from cropping. Most of the PSII is exported from the Burrum and Mary basins.

Other sources of pollutants include point sources (intensive animal production, industrial activities, mining, rural and urban residential, waste treatment and disposal, ports/marine harbour etc.). Compared to diffuse sources, most point source contributions are small but can be locally important and over short time periods.

The 'ABCD' water quality risk framework developed through the Paddock to Reef Monitoring and Modelling Program has been used as the basis of assessing the potential for management to reduce water quality impacts from the sugarcane and grazing industries. A is refers to cutting-edge practices that require further validation, B is current 'best-management practice, C is common practices and D is superceded/below industry practice.

Both Urban and horticultural impacts are an important and growing part of the water quality threats to marine and coastal ecosystems from land-based activities in the region, however quantitative assessment of both was not able to be included in this WQIP due to a lack of data. funding).

7.1 Contributing major land uses

The major contributions to pollutant loads in the Burnett Mary region result from agricultural land uses (grazing, sugarcane, horticulture and cropping), stream bank erosion, and urban areas. The modelled loads of constituents[8] are set out in the tables and graphs below and have been reproduced from the Paddock to Reef Source Catchment model for the Burnett Mary region. This

[8] Paddock to Reef's Source Catchment modelling reports loads as a total load consisting of a pre-development and anthropogenic component. Pre-development loads are the loads estimated prior to agricultural and urban development. Anthropogenic loads represent loads estimate the loads attributed to human activity and that management can address. A 2008-09 model run was used as the baseline for this WQIP.

section examines the contribution of the major land uses to the anthropogenic loads of water quality constituents consistent with the Reef Plan targets described in section 6.

Table 5. Annual anthropogenic loads of fine sediment and particulate nutrients (TSS, PN, PP) by land use.

	Total Suspended Sediment (000's tonnes / yr.)		Particulate Nitrogen (tonnes / yr.)		Particulate Phosphorus (tonnes / yr.)	
Land use	**Anthropogenic load**	**% Anthropogenic load**	**Anthropogenic load**	**% Anthropogenic load**	**Anthropogenic load**	**% Anthropogenic load**
Sugar Cane	15	**4**	84	**13**	19	**9**
Grazing	92	**27**	133	**21**	56	**27**
Horticulture	1	**0**	24	**4**	6	**3**
Urban	19	**6**	117	**18**	35	**17**
Other	1	**0**	6	**1**	2	**1**
Cropping	5	**1**	11	**2**	7	**3**
Forestry	3	**1**	18	**3**	5	**2**
Stream	209	**61**	240	**38**	74	**36**
Conservation	0	**0**	2	**0**	0	**0**
Total	**345**		**635**		**204**	

Table 6 Annual anthropogenic loads of dissolved water quality constituents (DIP, DIN, and PSII Herbicides) by land use.

	Dissolved Inorganic Nitrogen (tonnes / yr.)		Dissolved Inorganic Phosphorus (tonnes / yr.)		PSII Herbicides (tonnes / yr.)	
Land use	**Anthropogenic load**	**% Anthropogenic load**	**Anthropogenic load**	**% Anthropogenic load**	**Anthropogenic load**	**% Anthropogenic load**
Sugar Cane	361	83	6	**10**	25	31
Grazing	37	8	16	**27**	10	12
Horticulture	10	2	10	**17**	0	0
Urban	23	5	8	**14**	0	0
Other	1	0	0	**0**	0	0
Cropping	2	0	4	**7**	48	57
Forestry	3	1	2	**3**	0	0
Stream	1	0	12	**20**	0	0
Conservation	0	0	1	**2**	0	0
Total	**437**		**59**		**83**	

7.1.1 Total Suspended Solids

Stream banks and grazing are the dominant contributors of TSS (Figure 16). Most of the TSS is exported from the Mary and Baffle basins, (see section 4.2). Although the Baffle basin is less developed than the Burnett, Burrum and Kolan, its TSS contribution is relatively high because of the absence of water storages, its proximity to the Reef lagoon and relatively high rainfall (and runoff). Of the baseline anthropogenic TSS export, 61% is delivered through stream bank erosion, 27% of the TSS load comes from grazing, 6% from urban sources, 4% from sugar cane and the remainder from other sources (cropping, horticulture, conservation and other). Hill slope erosion is estimated from the Paddock to Reef Source Catchment model to be the dominant contributor to TSS export in the Baffle, Kolan, Burnett and Burrum basins. Recent work in the Burnett catchment by Simon (2014) suggests much higher stream bank contributions than estimated using Source Catchments and thus there is uncertainty regarding relative contribution of paddock, waterway and gully load contributions overall. Urban development, although a small contributor overall as shown in Figure 16, can be a locally high impact source of suspended sediment (Kroon et al. 2013), particularly during the development phase.

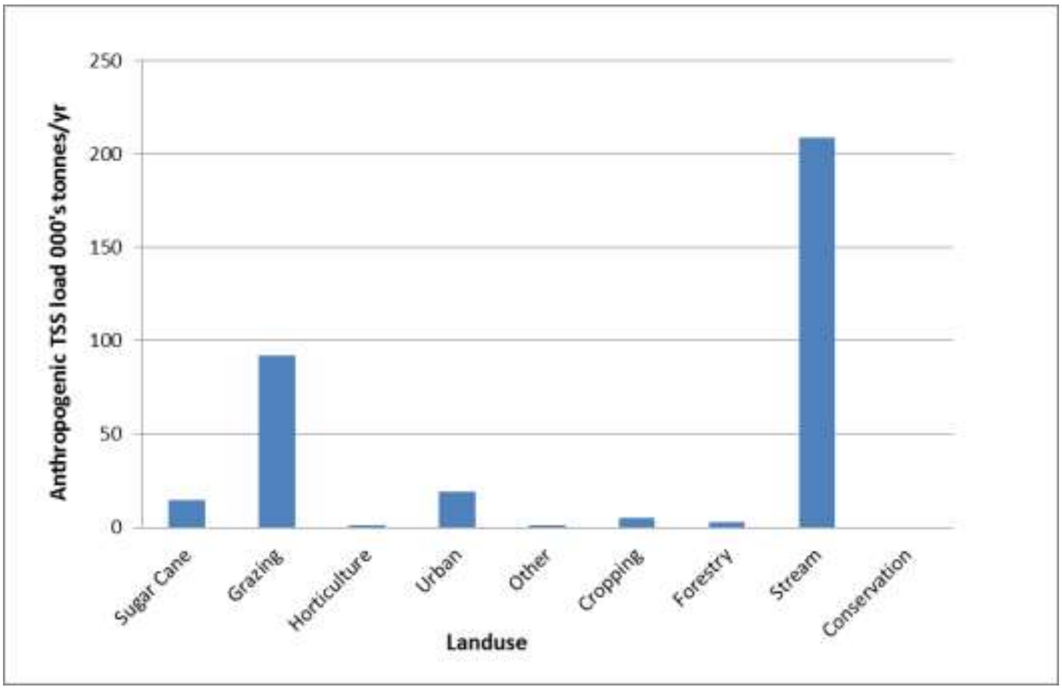


Figure 16. Annual anthropogenic load estimates for Total Suspended Solids (TSS) from major land uses

7.1.2 Particulate nutrient losses

Nutrient losses (both N and P) occur from both particulate (nutrients lost when soil is eroded) and dissolved sources which largely occur through fertiliser application. The majority of particulate losses come from and stream bank erosion (38% of the PN load and 36% of the PP load) and grazing (21% of the PN load and 27% of the PP load) (Figures 17 and 18). Urban losses are also predicted as important (18% of the PN load and 17% of the PP load)). The largest PN and PP losses are estimated from the Mary catchment, due to the importance of stream bank erosion, the lack of water storages to trap sediment and the size of the catchment (Park et. al, 2014).

7.1.3 Dissolved Inorganic Nitrogen

Dissolved N loss occurs largely from fertiliser application to intensive land uses, such as sugarcane, horticulture and dairying. About 83% of the anthropogenic baseline Dissolved Inorganic Nitrogen (DIN) export is predicted from sugarcane (Figure 19).

The sources of DIN from grazing and nature conservation lands are low, given the lack of fertiliser application. The anthropogenic proportion of the DIN load exported from the Burnett Mary region is estimated to be on average 437 tonnes per year, which is around ~80% of the total load (Park et al. 2014).

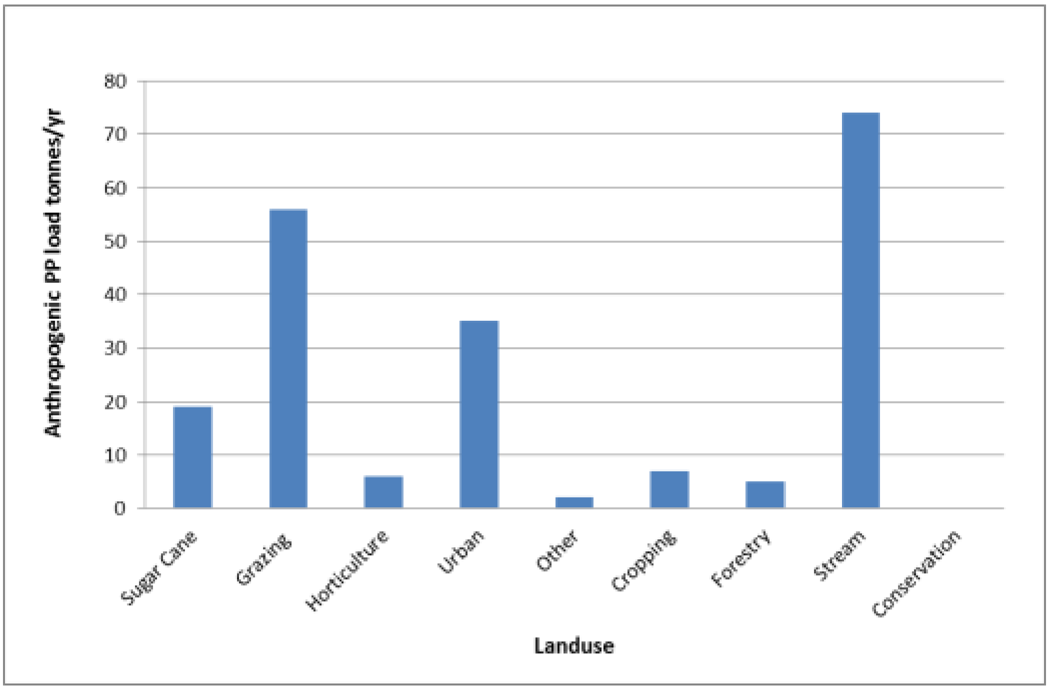


Figure 17 Annual anthropogenic load estimates for Particulate Phosphorus (PP) from major land uses

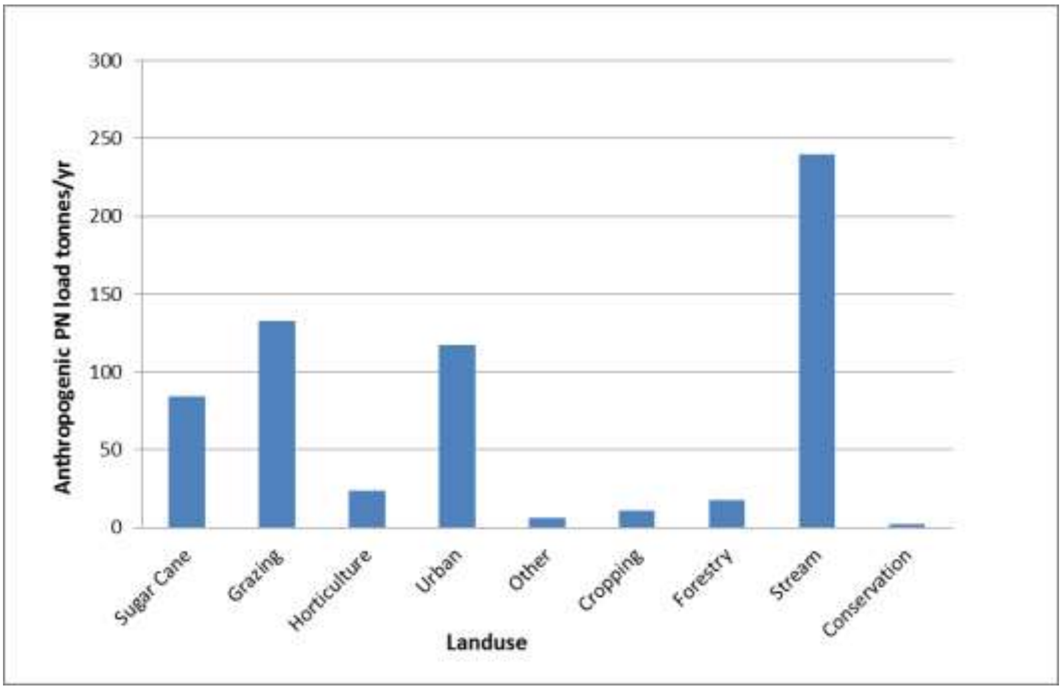


Figure 18 Annual anthropogenic load estimates for Particulate Nitrogen (PN) from major land uses

7.1.4 Dissolved Inorganic Phosphorus

Relative to DIN, DIP has received less attention in Reef programs. It is however very important, recognised in both RPTs and ERTs. Furthermore, in view of the feasibility problems associated with meeting 50% DIP (reported in Section 6), DIP warrants increased attention in future.

Approximately 59 t/year DIP is lost from the Burnett Mary region due to human activity and of this 27% is estimated to be come from grazing and 20% from streams (Figure 20). Given that DIP losses occur largely from heavy fertiliser applications, it could be expected that the amounts estimated from sugar cane and horticulture would be higher and grazing and stream bank contributions to be lower. It is possible that the results are an artefact of model assumptions.

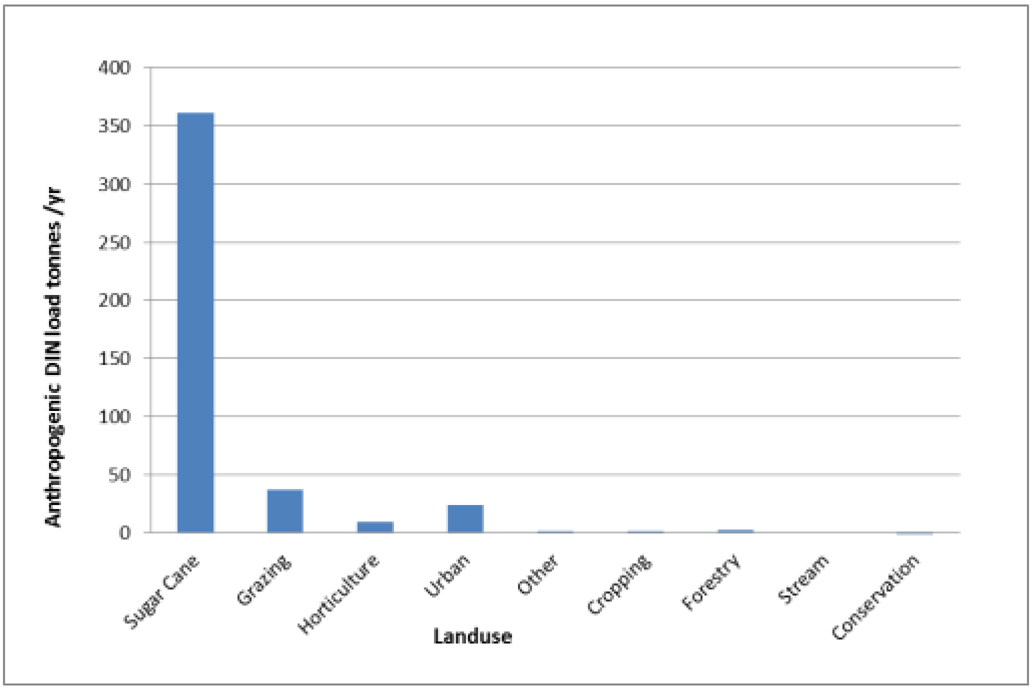


Figure 19 Annual anthropogenic load estimates for Dissolved Inorganic Nitrogen (DIN) from major land uses

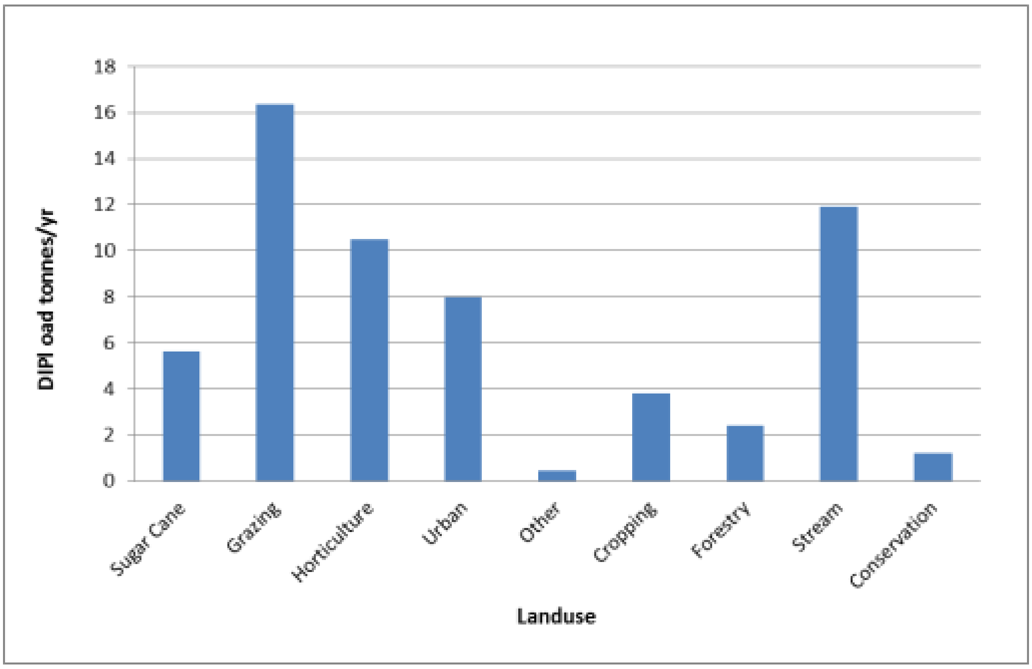


Figure 20 Annual anthropogenic load estimates for Dissolved Inorganic Phosphorus (DIP) predicted from major land uses

7.1.5 Dissolved Inorganic Phosphorus

Relative to DIN, DIP has received less attention in Reef programs. It is however very important, recognised in both RPTs and ERTs. Furthermore, in view of the feasibility problems associated with meeting 50% DIP (reported in Section 6), DIP warrants increased attention in future.

Approximately 59 t/year DIP is lost from the Burnett Mary region due to human activity and of this 27% is estimated to be come from grazing and 20% from streams (Figure 20). Given that DIP losses occur largely from heavy fertiliser applications, it could be expected that the amounts estimated from sugar cane and horticulture would be higher and grazing and stream bank contributions to be lower. It is possible that the results are an artefact of model assumptions.

7.1.6 Pesticides (PSII Herbicides)

Across the Reef catchments, photosystem II inhibiting herbicides, depending upon their scale of application, can be important pollutants in cropping, forestry, horticulture and sugarcane. Atrazine, ametryn, hexazinone and diuron are used predominantly in the sugarcane industry, with atrazine also being used in grains cropping. Tebuthiuron and simazine can be used the beef and plantation forestry land use (Kroon et al. 2013; Waterhouse et al. 2014).

Within the Burnett Mary region, sugarcane contributes about 31% of the (anthropogenic load) PSII export. The majority (approximately 57%) comes from cropping which this WQIP has not been able to take into account due to lack of economic analysis. Most of the PSII is exported from the Burrum and Mary basins (Park et al. 2014).

Pesticide usage across the Reef catchments is constantly changing in response to new pesticides being developed, as well as increasing costs and regulations forcing growers to adopt new chemicals and methods of application For example, in some Reef catchments a large peak in diuron concentrations was observed just prior to the introduction of changed rules regarding permitted usage patterns by the Australian Pesticides and Veterinary Medicines Authority (Kroon et al. 2013).

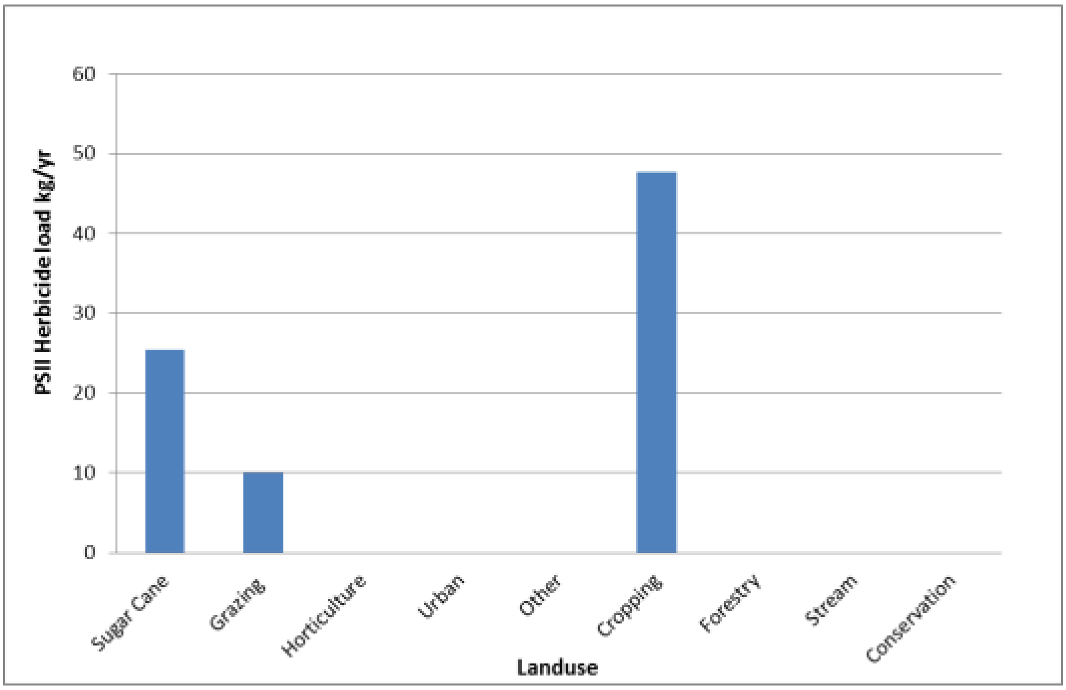


Figure 21 Annual load estimates for PSII Herbicides from major land uses.

7.1.7 Other pollutants

Other sources of pollutants to the Reef include point sources such as intensive animal production, manufacturing and industrial activities, mining, rural and urban residential, transport and communication, waste treatment and disposal, ports/marine harbour and shipping. Compared to diffuse sources, most point source contributions are relatively small but could be locally important and over short time periods. Point sources are generally associated with regulated activities, however, monitoring and permit information is not always available (Kroon et al. 2013).

7.2 Reducing agricultural impacts BMPs in grazing and sugar cane

The focus of government and industry programs to improve water quality is on development and implementation of agricultural management practices through the 'ABCD' water quality risk framework developed through the Paddock to Reef Monitoring and Modelling Program. The ABCD framework is intended to be adaptive. Communication about the different levels and standards of management practice within an industry (Thorburn et al. 2013) is an important part of the process. As knowledge improves and industry adapts practices are refined and could be expected to move between categories as industry innovation occurs. The principles of the ABCD framework are summarised for sugarcane and grazing in Table 7 below, and apply to all industries.

Table 7 Summary of the ABCD framework for sugar cane and grazing industries (from Australian Government & Queensland Government, 2011)

	A	B	C	D
Sugar cane	Cutting-edge practices that require further validation of environmental, social and economic costs/benefits	Currently promoted practices often referred to as 'Best Management Practices'.	Common practices. Often referred to as 'Code of Practice'.	Practices that are superseded or unacceptable by industry and community standards.
Effect on resource condition	When validated, practice likely to achieve long term resource condition goals if widely adopted.	Practice likely to achieve medium term resource condition goals if widely adopted.	Practice unlikely to achieve acceptable resource condition goals if widely adopted.	Practice likely to degrade resource condition if widely adopted.
Grazing	Practices are highly likely to maintain land in good (A) condition and/or improve land in lesser condition	Practices are likely to maintain land in good or fair (A/B) condition and/or improve land in lesser condition	Practices are likely to degrade some land to poor (C) condition or very poor (D) condition	Practices are highly likely to degrade land to poor (C) or very poor (D) condition
Soil erosion and water quality risk associated with grazing land management	Very low risk	Low risk	Low to moderate risk	Moderate to high risk

For the WQIP, the ABCD framework was interpreted to assess management impacts through the bioeconomic modelling framework, using current Paddock to Reef modelling as the basis of quantifying impacts. For sugarcane and grazing the 'high-level practices' from the Reef Plan 3 water quality risk framework (Queensland Government 2013a; Queensland Government 2013b) were used as the basis of the A, B, C and D level management practices; the 'supporting actions' were not directly considered because their impacts were not able to be quantified and would be expected to be low anyway.

A summary of the practices used for sugar cane used for the WQIP were:

- fertiliser rates
- fallow management
- placement of fertiliser
- tillage
- traffic
- trash blanket.

For grazing the summarised land management practices were:

- Average stocking rates are consistent with district long-term carrying capacity benchmarks for comparable land types, current land condition and level of property development.
- Retention of adequate pasture and groundcover at the end of the dry season (pasture assessment and stock management) informed by (a) knowledge of groundcover needs and (b) deliberate assessment of pasture availability in relation to stocking rate in each paddock during the latter half of the growing season or early dry season.
- Strategies implemented to recover any land in poor or very poor condition (C or D class).
- The condition of selectively grazed land types is effectively managed.
- Waterway (riparian management) and gully management practices were:
- Waterways - timing and intensity of grazing is managed in frontages of rivers and major streams (including associated riparian areas).
- Gully remediation – strategies implemented, where practical and affordable, to remediate gullied areas.

The detail of the ABDC practices for the high level practices are outlined in van Grieken *et al*. (2014) for sugarcane (van Grieken et al. 2014) and Pannell *et al*. (2014) for grazing (Pannell et al. 2014).

7.3 Reducing urban impacts

Urban impacts are an important and growing part of the water quality threats to marine and coastal ecosystems from land-based activities. A quantitative assessment of urban impacts was not able to be included in this WQIP due to a lack of data to inform the bioeconomic model ad INFFER process.

This section summarises important issues to be considered in managing urban impacts. As improved knowledge and data are developed anassessment of costs and impacts associated with urban development could be completed.

The total urban land use area in the Burnett-Mary region is 1,234km^2 or 2.3% of the total area (Fentie et al. 2014). The most significant urban areas in the coastal proximity are Maryborough, Hervey Bay and Bundaberg including the Woongarra Coast from Elliot Heads to Burnett Heads.

Urban impacts on water quality are typically classified into two catergories, point and diffuse source pollutants. A point source is a single, identifiable source of pollution, such as a pipe or a drain. Industrial wastes are commonly discharged to rivers and the sea in this way. In Queensland, point source and sewerage discharges from environmentally relevant activities[9] are regulated under the Environmental Protection Act 1994 (Environmental Protection Act, 1994).

Urban development changes the type and nature of water flow across the land. The impervious areas of developments, such as roads, roofs, driveways and footpaths, prevent water from infiltrating and evapotranspiring. Stormwater flows more often and in greater volumes than would happen naturally because of a system of pits and pipes to receiving waterways. Stormwater from street surfaces is often contaminated with car oil, dust and the animal manure and soil and sediment run-off from construction sites, and in industrial areas often contains more toxicants and chemicals.

By mass, the most important pollutant is suspended sediment generated through erosion of construction areas and vegetation removal. The problem is sharply exaggerated in developing areas with sediment generation rates being up to forty times greater than in established urban areas due to the highly exposed conditions (Lewis et al., 2008).

7.3.1 Developing Urban

Over the next 20 years, regional population growth will increase and thus the urban pressures on the marine and coastal ecosystems will increase.

The estimated total population of the Wide Bay-Burnett Region (which covers the majority of the Burnett Mary region) as of 2013 was 286,705, distributed across five regional and one shire council.

The population is projected to expand by 31% or over 90,000 residents by 2031, 76% of which is expected to occur in the Fraser Coast and Bundaberg Regional Council areas (Queensland Government 2014b). Most expansion will be concentrated within the urban centres of Bundaberg, Maryborough and Hervey Bay, all of which are close to the coast and with high connectivity to the marine environment (Department of Local Government and 2011).

Table 8. Estimated 2013 and projected 2031 populations for council areas in the Widebay-Burnett region

Council Area	2013 population[10]	2031 population[11]
Bundaberg	93,976	116,476
Cherbourg	1,286	1,497
Fraser Coast	100,297	146,602
Gympie	48,145	60,567
North Burnett	10,360	10,325
South Burnett	32,641	41,439
Total	***286,705***	***376,906***

[9] Environmentally relevant activities that are prescribed activities are generally industrial activities but also include some agricultural activities. A full list of all of the prescribed ERAs can be found in schedule 2 of the Environmental Protection Regulation 2008 (http://www.legislation.qld.gov.au/Acts_SLs/Acts_SL_E.htm).

[10] 2013 population estimates taken from Queensland Government, 2014b.

[11] 2031 population projections taken from Department of Local Government and Planning, 2011.

Table 9 shows the estimated rate of urban expansion expected by 2031 in the 3 major centres in the region.

Table 9: Current urban footprint and estimated urban expansion by 2031 for major coastal centres in the region. All values in Ha (from Department of Local Government and Planning, 2011).

		Bundaberg	Maryborough	Hervey Bay	Total
Current footprint		**4291**	**1507**	**2382**	**8180**
Increase by 2031	Commercial	160	7	39	206
	Industrial	223	94	83	400
	Residential	1736	265	973	2974
	Other	351	0	0	351
	Total	2470	366	1095	3931

A key to reducing urban impacts on water quality is in best management of developing urban areas. Management during both the development phase and post development phase need to be considered carefully.

The most effective approach is in the pre-development design phase. A properly implemented Erosion and Sediment Control Management Plan (ESCMP) can limit the transport of material from active development sites into waterways (Healthy Waterways Partnership n.d.) and water sensitive urban design (WSUD) incorporates water quality improvement measures for post-development outcomes (Water by Design 2007). These frameworks provide development guidelines that can help ensure compliance to current Queensland State Government legislative instruments relevant to coastal development.

The BMRG will work with local councils to increase awareness of complying with all urban best management practices. The BMRG will also work with partners to better quantify urban load and BMP quantification within the Source Catchment modelling framework, in future enabling assessment of the cost-effectiveness of urban and agricultural management. Without this information there is little basis on which to design programs to reduce urban loads.

7.4 Reducing horticultural impacts

Table 10 : Horticulture production areas (ha) and exported loads (kg/y except for Sediment which is t/y).

Basin	Area	TSS	PN	DIN	DON	PP	DOP	FRP
Burnett	10293	161	1965	742	1343	527	188	880
Baffle	1626	128	1580	711	940	433	136	636
Burrum	6480	385	4732	2034	2915	1300	420	1963
Kolan	3181	192	2365	1023	1434	649	208	969
Mary	8024	1071	16406	6117	9669	4499	1356	6164
Total	29604	1937	27048	10627	16301	7408	2308	10612

Horticulture in the Burnett Mary region represents a challenging case for catchment managers. "Horticulture" is best thought of as a collective term grouping together an array of industries and production processes including perrenial and seasonal crops. Estimated horticulture production areas and modelled export loads(Fentie et al. 2014) for each drainage basin in the Burnett Mary region are given in Table 10. At the GBR scale the total area of 29604ha is significant and comprises 39% of the entire aggregated horticulture estate (including bananas).

A very diverse range of vegetable production occupies and estimated 7768ha in the region. Beans, cucurbits, potatoes, sweet potatoes, tomatoes and capsicum account for the majority of the vegetable production area. The other dominant category of horticulture production falls broadly under the heading of orchard fruits and nuts which cover an estimated area of 14670ha. The bulk of orchard production is accounted for with macadamias, citrus, avocado and mango plantations. Smaller, but notable orchard crops in the region include lychees, stone fruit (including olives) and pecans

Although horticultural activities occupy relatively small areas, they are almost always both high intensity and in relatively close proximity to the coast. Because of the diversity of enterprises, assessment of horticultural loads and BMP impacts are always difficult. This is further complicated by the co-existence of cane and small crops on some properties in the Burnett Mary region.

BMRG will look for opportunities to work with horticulture (particularly through GrowCom) to better quantify horticultural impacts and opportunities. Without this information there is no transparent basis on which to design programs to assist horticulture meet its share of load reduction targets.

8 Prioritisation and Benefit:Cost results for cane and grazing

Achievement of the water quality targets requires practice changes in agricultural industries. While change across all industries is required, the emphasis in the WQIP is on sugar cane and grazing. This is because of their importance in terms of contribution to water quality impacts and the documented level of understanding of practice impacts and potential for reduction.

For sugarcane farms, moving from D to C and/or B practice is estimated to be profitable for those farms ranging from small to large in size. It appears generally not profitable to move to A class practices, except in some circumstances on larger farms. The degree to which it is attractive for landholders to move from C to B practices is estimated to be strongly related to farm size, being predicted as profitable on large farms but not profitable for small farms; relatively low levels of adoption from C to B practices can be expected on small farms.

For grazing, particularly when taking into account non-profit related barriers, it is estimated that there are always net costs to farmers to change practices, regardless of farm size. Overall, results suggest that it will be extremely difficult to achieve practice change at large scale in the grazing industry without paying farmers to overcome profit and non-financial barriers to achieving water quality outcomes for paddock management practices as well as stream bank and gully fencing.

Bioeconomic modelling is a powerful tool to assess benefits and costs of meeting either RPT or ERTs, at both whole of region or individual basin scale. Sugarcane up to B practice is always preferentially selected over grazing in attempting to meet targets because of the net profitability to improve practices to B level. The higher the target, the more management changes need to occur in unprofitable practices (A practices in sugarcane and all practices in grazing management, stream and gully fencing). RPTs and ERT scenarios involved meeting TSS, DIN, PN, PP and PSII targets; meeting DIP targets at desired levels was infeasible.

Meeting pollutant targets on an individual basin scale is much more expensive than if target can be met on a whole of region scale; for example the net cost is estimated to be approximately $4.9 million/year higher for meeting RPTs on an individual basin basis compared with whole of region.

At a whole of region scale, ERTs pose <u>at least</u> an additional $13.4 million net loss/year on agriculture than for RPTs. Meeting ERTs also poses feasibility issues because particulate losses come mostly from grazing land uses, stream bank and gully erosion, all of which come at a large cost. Achieving targets in the Mary basin is particularly challenging. If ERT scenarios have to be met then stronger consideration of the trade-offs, such as the importance of protecting natural assets (for example seagrass and dugongs) compared with the local beef industry is required.

Scenarios assessing meeting either RPTs or ERTs at the whole of region scale were chosen as the basis for the WQIP. For both RPTs and ERTs in sugarcane all land is required to move to at least B practice. For the ERTs the majority of land (over 46,000 ha) in sugarcane is estimated to be required to be in A practice. The picture in grazing land management is even more challenging, with more than 131,000 additional ha required in A practice for RPTs and almost twice that to achieve ERTs. Unrealistically low stream bank and gully fencing predictions could be artefacts of the modelling assumptions.

Given the challenges with the ERT scenario, plus the fact that RPTs better represent currently agreed targets by the Australian and Queensland governments, the RPTs at whole of basin scale have been selected as the basis of developing the WQIP Implementation Program.

To meet sediment RPTs large changes in land management practices are required from grazing subcatchments in the Mary, Burnett and Kolan and to a lesser extent the Baffle and Burrum (Gregory River). Both cane and grazing are targeted for sediment load reduction; cane is targeted where other constituents can also be reduced and where practices are profitable.

Very large DIN loads are associated with sugar cane growing areas in the lower Kolan, Burnett, Burrum (particularly Elliot and Gregory rivers) and the Mary catchments, with DIN reductions targeted largely to where the major loads are coming from. High pesticide loads and need for reductions come from sugar cane subcatchments.

Because of the large costs in grazing compared with cane, most of the grazing area is not targeted for the WQIP. Net profit is largely associated with sugarcane in the Kolan, lower Burnett and Burrum basins (Elliot and Gregory catchments in particular) and in selected other subcatchments. Large net losses occur in many subcatchments in the Mary and Baffle basins, because sediment reductions are required from grazing areas which are always estimated to incur a loss.

INFFER was used to assess the benefits and costs associated with meeting the whole of region RPT and ERT scenarios. In addition to the direct net costs associated with practice change, INFFER includes additional costs needed to run and administer the program of works and agency activities needed to achieve WQIP implementation.

The RPT and ERT scenarios differ in terms of the scale of the nutrient and sediment reduction targets, overall cost and cost-effectiveness. Achieving the ERTs, while feasible is very costly ($90 million in the initial 5 years). In contrast, achieving the RPTs was estimated to come at a cost of $32.5 million over 5 years, and is three times as cost-effective as achieving ERTs. Current political constraints (lack of guaranteed long-term funding and socio-political risks) were major reasons for calculated benefit:cost ratios of less than 1 (i.e. costs exceed benefits); if these risks could be reduced then it is possible that benefits could exceed costs.

The INFFER analysis supports the notion that the RPT scenario is more realistic and acceptable for implementation than the ERT scenario, albeit still very challenging to both government and industry. To achieve either RPTs or ERTs will require significantly increased levels of funding, much beyond that currently available, with more significant impacts on agriculture than is being discussed).

8.1 Farm level financial economic analysis - cane and grazing

Achievement of water quality targets, RPTs and ERTs, requires practice changes in agricultural industries. While change across all industries will be required, the emphasis here is on sugar cane and grazing because of their importance in contributing to water quality issues and the level of understanding of practices that are estimated to have impacts. Financial economic analysis has been conducted for both industries as part of the WQIP, as summarised in Section 5. A more detailed overview of the methods, assumptions and results can be found in van Grieken *et al*. (2014) and Pannell *et al*. (2014).

A summary of the farm level financial economic analysis for each industry is presented below, which provides context for understanding the overall catchment scale benefit cost analysis results presented in the following section.

8.1.1 Cane

The farm level financial economic analysis for sugar cane was conducted for three representative farm sizes (small 75 ha, medium 125 ha, large 250 ha) and two soil conditions (well drained and less well drained). The analysis included consideration of non-profit related barriers and transaction costs. Results are summarised in Table 11 and are expressed as net annual equivalent annual benefits.

Table 11 Change in net annual equivalent benefits ($/ha/year) for management changes in sugar cane in the Burnett Mary region on two soil types for small, medium and large farms. Reproduced from van Grieken et al. (2014).

Soil	Well drained			Less well drained		
Farm size	Small (75 ha)	Medium (125 ha)	Large (250 ha)	Small (75 ha)	Medium (125 ha)	Large (250 ha)
Practice change shift						
D to C	141	189	209	105	152	172
D to B	145	289	313	180	323	348
D to A	-72	158	2	-40	191	234
C to B	-72	54	90	-1	126	161
C to A	-290	-76	-26	-221	-7	44
B to A	-312	-187	-136	-314	-189	-138

Moving from D to C or D to B practices is estimated to be profitable (positive annual equivalent net benefits) for farms ranging from small to large in size. It appears generally not profitable to move to A class practices, except in some cases on larger farms. These findings are consistent with current industry and government views. The degree to which it is attractive for landholders to move from C to B practices is strongly related to farm size, it being predicted as profitable on large farms but unprofitable on small farms. The implications are that relatively low levels of adoption from C to B practices are likely to occur particularly on small farms.

8.1.2 Grazing

The financial economic analysis for grazing in the Burnett Mary region was conducted for three representative farm sizes (small 288ha, medium 880 ha, large 4134 ha) and across three land productivity (high, medium and low) classes (Whish 2012). Both profit and non-profit related financial barriers were also taken into account in the analysis, as outlined in Pannell *et al*. (2014).

Results for the medium productivity land type are shown below Table 12. Before non-profit related barriers were taken into account, with the exception of restoring degraded land (practice 3), all other practices were assessed to be profitable (data not shown in the Table below), albeit sometimes only slightly. However, when non-profit related barriers were taken into account, annual equivalent net benefits were always negative across all farm sizes (as shown by the negative annual equivalent benefits).

There are a number of non-financial barriers to adoption. It is well recognised in the literature on adoption of farm innovations (e.g. Pannell *et al*. 2006) that there are various non-profit barriers that can affect adoption decisions.

- Perceived riskiness of the new practices
- Uncertainty about the performance of the new practices
- Complexity of the new practices
- Perceived incompatibility of new practices with the existing farming system
- The costs of learning about the new practices.

Financial viability issues of the Queensland beef industry in general and the Burnett Mary region in particular have been identified in a range of studies (ABARES 2013, McCosker et al 2010, Mackenzie *et al*. 2005). Adoption on small farms poses particular challenges. Small farms occur in much of the

Mary catchment as well as in areas within a one hour's drive of town centres (Marie Vitelli Agforce, personal communication). Large scale practice changes are unrealistic to expect given farm viability and farm size issues and are even more difficult with when additional non-financial barriers are included.

While the results in Table 12 are shown for the medium land productivity class the overall pattern was similar across the high and low land productivity classes. Overall, when non-profit related barriers are taken into account, it is estimated to be extremely difficult to achieve practice change at large scale in the grazing industry without paying farmers to overcome profit and non-financial barriers to achieve water quality outcomes.

Table 12 Change in annual equivalent net benefits ($/ha) estimated on medium productivity land classes (including up-front costs)

Practice shift	Small farm (288 ha)	Medium farm (880 ha)	Large farm (4143 ha)
Required annual incentive payment ($/ha of land in the initial land condition)			
Practice 1[A] D to C	-51	-50	-50
Practice 1 C to B	-52	-51	-50
Practice 1 B to A	-28	-26	-25
Practice 2[B] D to C	-26	-25	-25
Practice 2 C to B	-75	-75	-75
Practice 2 B to A	-28	-26	-25
Practice 3[C] D to B	-160	-135	-116
Practice 4[D] D to C	-16	-15	-15
Practice 4 C to B	-68	-43	-25
Practice 4 B to A	-68	-43	-25

[A] Average stocking rates on paddocks are consistent with district long-term carrying capacity benchmarks for comparable land types, current land condition and level of property development, [B] Retention of adequate pasture and groundcover at the end of the dry season, [C] Strategies implemented to recover land in poor or very poor condition (C or D class), [D] The condition of selectively grazed land types is effectively managed

8.2 Waterway and gully costs

Stream costs were calculated as $ 3,886/km/ year and gully costs as $3,582/km/year, based on assumptions developed in group workshops regarding fencing and off-stream watering costs. Both up-front and maintenance costs were considered and a 6% discount rate (same discount rate as used for the sugar cane and grazing analysis) was used. The stream and gully costs should be considered a 'ballpark' figure – in reality there will be large variation in the costs of livestock exclusion and site specific tailoring of costs for particular conditions could lead to more cost-effective outcomes than our results suggest.

8.3 Costs and implications of achieving Reef Plan and Ecologically Relevant Targets

As outlined earlier, based on the re-interpretation of Reef Plan targets and the development of Ecologically relevant targets (outlined in Section 6), four scenarios were selected to be of most interest to help inform decision-making regarding the implementation focus of the WQIP:

Table 13. Load reductions targets by constituent

<table>
<tr><th rowspan="3">Scenario</th><th colspan="6">Load Reduction Target by constituent</th></tr>
<tr><th colspan="5">(% Anthropogenic Load)</th><th>(% Total load)</th></tr>
<tr><th>TSS</th><th>PN</th><th>PP</th><th>DIN</th><th>DIP</th><th>PS II Herbicides</th></tr>
<tr><td>1. Reef Plan Targets (to be met in each basin)</td><td rowspan="2">20%</td><td rowspan="2">20%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">20%</td><td rowspan="2">60%</td></tr>
<tr><td>2. Reef Plan Targets (to be met across the region, with different targets attained in each basin)</td></tr>
<tr><td>3. Ecologically Relevant Targets (to be met in each basin)</td><td rowspan="2">20%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td rowspan="2">20%</td><td rowspan="2">60%</td></tr>
<tr><td>4. Ecologically Relevant (to be met across the region, with different targets attained in each basin)</td></tr>
</table>

Meeting the individual Basin targets requires that the target type (RPT or ERT) has to be met for each individual constituent in each of the 5 basins (Baffle, Kolan, Burnett, Burrum and Mary). In contrast, the whole of region targets only have to be met across the whole region. In all cases the bioeconomic model seeks to achieve the targets at least cost across both the sugar cane and grazing industries.

Because the economic analysis is limited to sugar cane and grazing, the four scenarios assume that the targets will be achieved only through actions in these industries. This means that these industries bear the burden of meeting the targets (and should also be the major recipients of public funding on this basis), whereas in reality other industries also contribute to the water quality issues.

8.3.1 Overview of results

As outlined in Section 6.2, achieving the 50% DIP target was not feasible, meaning that DIP is estimated to be the major constraint to feasibly achieving either RPTs or ERTs. As outlined earlier there has been much less modelling emphasis and scrutiny into DIP in Paddock to Reef modelling than for DIN, TSS and PSII, and thus it is possible that the result is an artefact of modelling assumptions[12]. Because of the uncertainty regarding DIP, the four scenarios reported below are set to meet all original targets with the exception of DIP which was set to 20%. When the DIP target is set at a level greater than 20% the costs rise dramatically and become infeasible beyond approximately 30%.

The results for Scenario 1 (meeting RPTs in each basin) indicate that targets are predicted to be achieved at a modest net profit in the Kolan and Burrum basins (Table 14). This occurs because of

[12] For example, the Paddock to Reef sugarcane synthesis table results show very different DIP practice efficiency figures between well drained (eg red dermosol) than poorly drained (eg redoxic hydrosol) soils which could have a large impact on bioeconomic modelling results.

their lesser size compared with the Burnett and Mary and the increased area of sugarcane as a proportion of land use. Net costs are predicted in the Baffle, Burnett and Mary basins because the practice change is also required in grazing to achieve the targets, which always incurs a net loss.

If RPTs only have to be met on a whole of region basis, then large savings can be made (see Scenario 2, Table 14). The net cost is estimated to be approximately $3.0 million/year compared with approximately $7.9 million/year from Scenario 1.

Table 14 Costs/Profits of attaining scenario targets for each basin in the Burnett Mary region

Scenario	Annual Cost/Profit ($ million/year)				
	Baffle	Kolan	Burnett	Burrum	Mary
1. Meet RPTs in each basin (20% DIP*)	$1.4M Cost	$0.5M Profit	$4.7M Cost	$0.5M Profit	$2.8M Cost
2. Whole region RPTs (20% DIP*)	$3.0M Cost				
3. Meet all ERTs in each basin (*20% DIP)	$4.2M Cost	$0.2M Profit	$7.8M Cost	$0.2M profit	Not feasible
4. Whole region ERTs (*20% DIP)	$16.4M Cost				

The difference between the RPTs and the ERTs are in the ambitiousness of the PN and PP targets – only 20% needs to be met under RPTs compared with 50% for ERTs. Meeting ERTs poses feasibility issues because particulate losses come mostly from grazing land uses, stream bank and gully erosion, all of which come at a large cost. As illustrated in Table 14, ERTs are not feasible to meet in the Mary catchment (Scenario 3). The estimation of predicted profitability in the Kolan and Burrum catchments should also be treated with caution and could be an artefact associated with the Mary infeasibility problem.

At a whole of region scale, ERTs pose at least an additional $13.4 million loss/year on agriculture than for RPTs. The actual costs might be higher[13,14]. The implication of the ERT scenarios especially are that very difficult decisions would be required to consider and trade-off the importance of protecting natural assets (for example seagrass and dugongs) compared with the local beef industry assuming that meeting targets equates to protecting environmental values. The alternatives under

[13] The bioeconomic model assumes stream remediation costs are fencing, off-stream watering and stock exclusion – if (as is likely) more expensive engineering options have to be used then stream remediation costs will be much higher.

[14] An additional issue is that sediment practice effectiveness for sugarcane is estimated from the Paddock to Reef cane synthesis table to be extremely high - 100% effective to move from C to B practice. If effectiveness is lower this could change results and increase costs further.

these circumstances might include land retirement from grazing (it could be cheaper to pay for land stewardship rather than production) or accept further decline in the marine environment.

Table 15 Anthropogenic load reduction achievements associated with four water quality target scenarios in the Burnett Mary region

Scenario	Net profit/cost ($million/yr.)	Load reductions (% achieved)				
	Whole Region	Baffle	Kolan	Burnett	Burrum	Mary
1. Meet RPTs in each basin (20% DIP*)	$7.9M Cost	TSS – 21.8, DIN – 55.4 PN – 135.7 PP – 107.4 DIP – 20 PSII – 60 $1.4M Cost	TSS – 23.5, DIN – 86.9 PN – 54.9 PP – 40.4 DIP – 24.9 PSII –60 $0.5M Profit	TSS – 36.2 DIN – 93.0 PN – 46.3 PP – 36.1 DIP – 20, PSII –60 $4,8M Cost	TSS – 39.5, DIN – 87.4 PN – 51.7, PP – 43.8, DIP – 20, PSII –60 $0.5M Profit	TSS – 20 DIN – 76.9 PN – 30.1 PP – 29.6, DIP – 20, PSII –60 $2.8M Cost
2. Whole region RPTs (20% DIP*)	TSS – 20 DIN – 83 PN – 40 PP – 37 DIP – 20 PSII – 60 $3.0M Cost	TSS – 15 DIN – 48 PN – 130 PP – 99 DIP – 13 PSII – 49 $0.8M Cost	TSS – 24 DIN – 87 PN – 55 PP – 41 DIP – 25 PSII – 62 $0.5M Profit	TSS – 20 DIN – 90 PN – 42 PP – 31 DIP – 4 PSII – 54 $0.9M Profit	TSS – 37 DIN – 86 PN – 50 PP – 42 DIP – 17 PSII – 57 $1.0M Profit	TSS – 19 DIN – 80 PN – 31 PP – 32 DIP – 24 PSII – 66 $4.6M Cost
3. Meet all ERTs in each basin (*20% DIP)	(net of individual basins is $11.6M Cost in 4 basins, not feasible in Mary)	TSS –51 DIN – 80 PN – 158 PP – 141 DIP – 48 PSII –71 $4.3M Cost	TSS – 31 DIN – 87 PN – 61 PP – 50 DIP – 26 PSII – 60 $0.2M[A] Profit	TSS –51 DIN – 97 PN –57 PP –50 DIP – 20 PSII –75 $7.8M Cost	TSS – 40 DIN – 87 PN – 55 PP – 50 DIP – 20 PSII – 60 $0.2[A] Profit	Not feasible
4. Whole region ERTs (*20% DIP)	TSS – 32 DIN – 87 PN – 50 PP – 50 DIP – 21 PSII – 79 $16.4 Cost	TSS – 61 DIN – 78 PN – 166 PP – 150 DIP – 45 PSII – 71 $4.9M Cost	TSS – 37 DIN – 93 PN – 72 PP – 64 DIP – 27 PSII – 82 $1.2M Cost	TSS – 35 DIN – 97 PN – 54 PP – 43 DIP – 5 PSII – 81 $2.1M Cost	TSS – 42 DIN – 90 PN – 66 PP – 62 DIP – 14 PSII – 78 $1.3M Cost	TSS – 27 DIN – 81 PN – 38 PP – 40 DIP – 20 PSII – 80 $6.9M Cost

One consequence of the optimisation approach of the bioeconomic model is that over-achievement of other constituents is possible (Table 15). This is because the model seeks to meet the targets using a least-cost solution and is a product of the combination of land uses, modelled loads and practices selected. This is illustrated through Scenario 1 – DIP and PSII are achieved whereas TSS is over-achieved by over 10% in the Burnett and Burrum, DIN is markedly over-achieved in all except the Baffle, and PN and PP are always exceeded by 10% or sometimes much greater. These results help to illustrate how sensitive the bioeconomic modelling results are to practice effectiveness assumptions and costs.

Table 15 also further illustrates that the whole of region targets (Scenarios 2 and 4) are much more efficient than if targets have to be met on an individual basin level. In these Scenarios achievement of load reductions occurs preferentially in the Basins where there is greater area of sugar cane (Kolan, Burrum, Burnett), because the load reductions can be achieved at a lower cost. Load reductions are then achieved in areas (typically dominated by grazing) that are more expensive. Achieving targets in the Mary basin is particularly challenging, because large amounts of sediment come from stream banks and grazing, and the costs of remediation are extremely high.

Given the feasibility issues and/or much larger costs of achieving targets at the individual basin level, implementation planning for the WQIP focuses only on the whole of region targets (Scenarios 2 and 4). Table 16-14 outline the extent of predicted changes in sugarcane, grazing, stream bank and gully remediation with the assumptions used to underpin the bioeconomic model. Results are presented at whole of region scale. Tables 15 and 16 for sugar cane and grazing respectively show the original area estimated under A, B, C or D practice, the area required to meet the target and the area change.

For both RPTs and ERTs in cane (Table 16) all land is required to move to at least B practice. For the ERTs the majority of land (over 46,000 ha) in sugar cane is predicted to be required to be in A practice. The picture in grazing land management is even more challenging (Table 17), with more than 131,000 additional ha required in A practice for RPTs and almost twice that to achieve ERTs.

Table 16 Summary of practices change shifts required in sugar cane to meet water quality targets

	A (ha)	B (ha)	C (ha)	D (ha)	Total (ha)
Cane – original	1614	5987	34082	15403	57087
Cane – new **RPTs whole region**	11045	46997	0	0	57087
ERTs whole region	46019	11066	0	0	57087
Cane area change **RPTs whole region**	+9431	+41010	-34082	-15403	
ERTs whole region	+44405	+5079	-34082	-15403	

Table 17 Summary of practices change shifts required in grazing to meet water quality targets

	A (ha)	B (ha)	C (ha)	D (ha)	Total (ha)
Grazing – original	568251	1870731	900266	287277	3626527
Grazing new **RPTs whole region**	699600	1857922	794810	274192	3626527
ERTs whole region	812066	1785690	766246	262523	3626527
Grazing area change **RPTs whole region**	+131349	-12809	-105456	-13085	
ERTs whole region	+243815	-85041	-134020	-24754	

Table 18 shows the predicted level of stream and gully remediation required. Given the importance of stream bank erosion in the Mary catchment, the stream and gully fencing estimates are surprisingly low, with very limited riparian or gully management predicted under either scenario.

The reasons for this arise from the model assumptions used including the extremely large costs associated with stream and gully work compared with practice change, and possible over-optimism of land management practice efficiencies and profitability results. The modelling results are extremely sensitive to practice effectiveness and cost assumptions; the model itself has been largely faithful to the current science/catchment modelling base, and the extent to which the results are to be believed depend upon the confidence in these results. Further scrutiny on the effectiveness of practices within and between industries as well as increased focus on the ability to remediate streams and gullies is required. Due to the uncertainty of some of the assumptions used in the model, these results need to be used as indicative rather than absolute. The assumptions are able to be updated as model conceptualisation knowledge advances.

Table 18 Summary of works estimated for waterways and gullies to meet water quality targets

Process and scenario	Quantity
Gullies km – modelled baseline length	7640 km
Gullies fenced*(km) **RPTs whole region (2)**	2 km
ERTs whole region (4)	0 km
Waterways (km) – modelled baseline length	6295 km
Waterways fenced*(km) **RPTs whole region (2)**	16 km
ERTs whole region (4)	760 km

8.4 Sediment and nutrient load reductions in sugarcane and grazing

The RPTs at whole of basin scale have been selected as the basis of developing the Implementation Plan for this WQIP for the Burnett Mary region. The bioeconomic model and its outputs provide priorities and direction for WQIP implementation and program design at the basin level scale. At this stage it should not be used to specifically target local level works prioritisation because the scale of the available Source Catchment modelling was relatively coarse and based on a baseline from 2008-09. The choice of where and how to target programs at the local scale will be influenced by a range of factors including (but not limited to); the priorities and objectives of government funding programs, an assessment of the site based risks associated with water quality, the existing level of practice of landholders, the willingness of landholders to participate in programs and local knowledge. Nevertheless these results provide a more quantifiable basis than the region has had previously.

The figures and graphs presented below depict how the change in load that would be achieved if the WQIP was fully implemented).

The figures and graphs are presented in groups of two:

- Change in pollutant loads predicted by the bioeconomic model. These maps show the reduction in pollutant loads that would result from full implementation of the WQIP.
- Change in loads that would result from meeting the Reef Plan Targets, using the outputs from the bioeconomic model. These graphs indicate the likely load reductions that would result from implementation of the WQIP if the plan is fully funded and implemented. Note that levels of adoption required are well beyond those likely with current levels of funding.

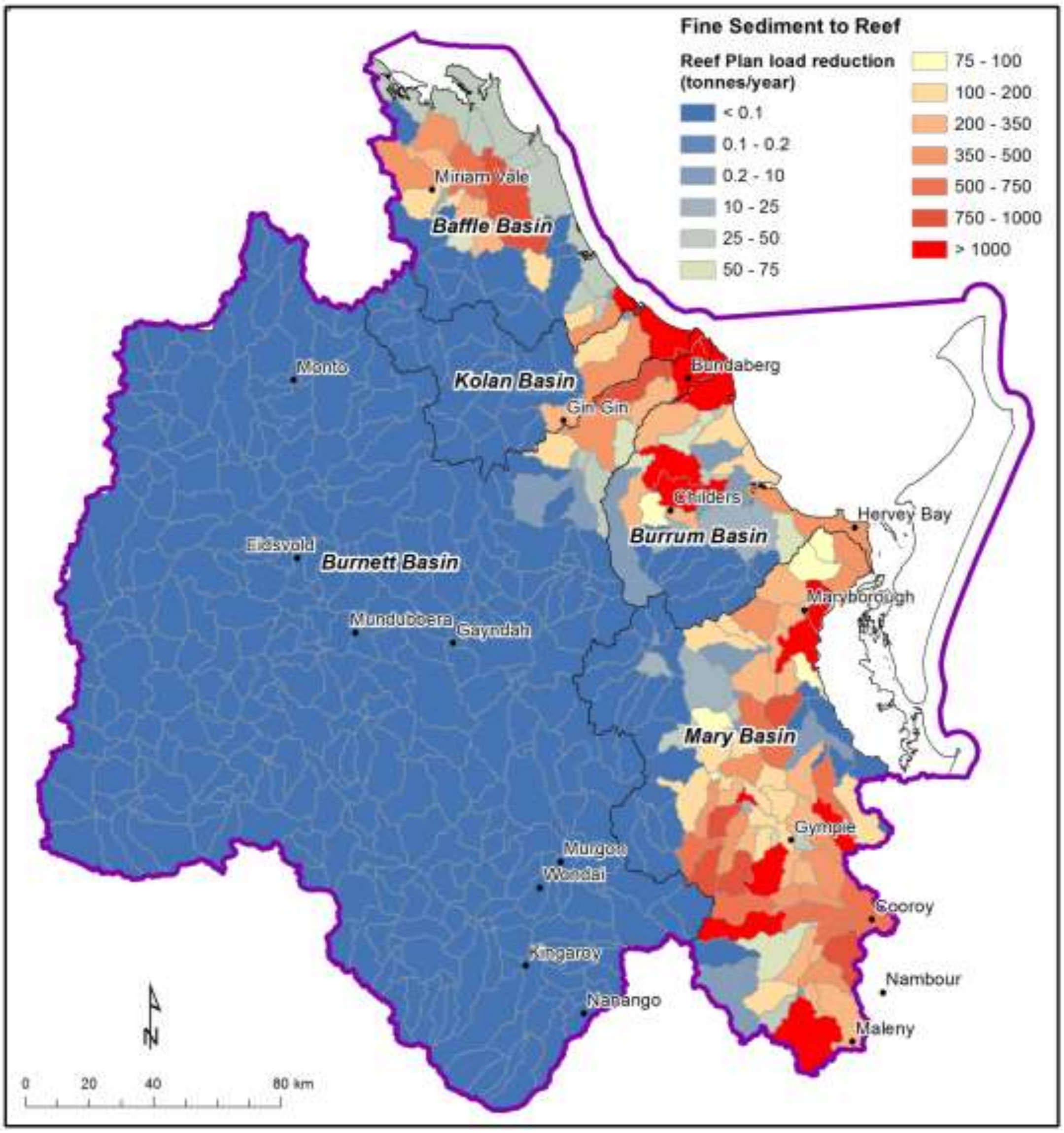


Figure 22 Reductions of TSS loads (t/yr.) from the Burnett Mary region assuming full implementation of WQIP to achieve Reef Plan targets.

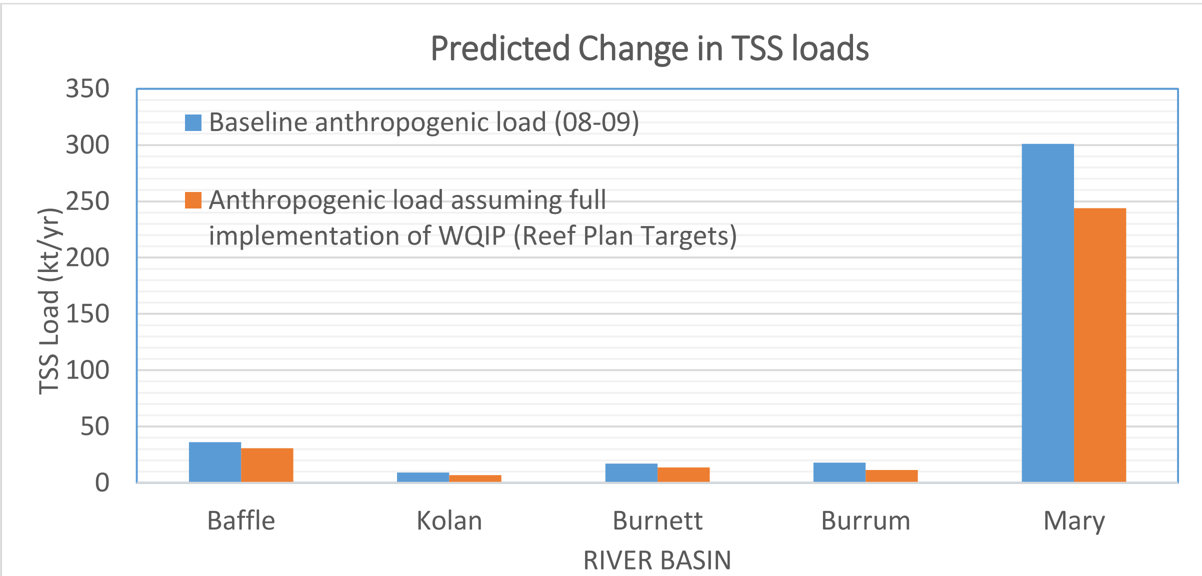


Figure 23 Predicted change in TSS load (000's t/yr.) assuming full implementation of the WQIP

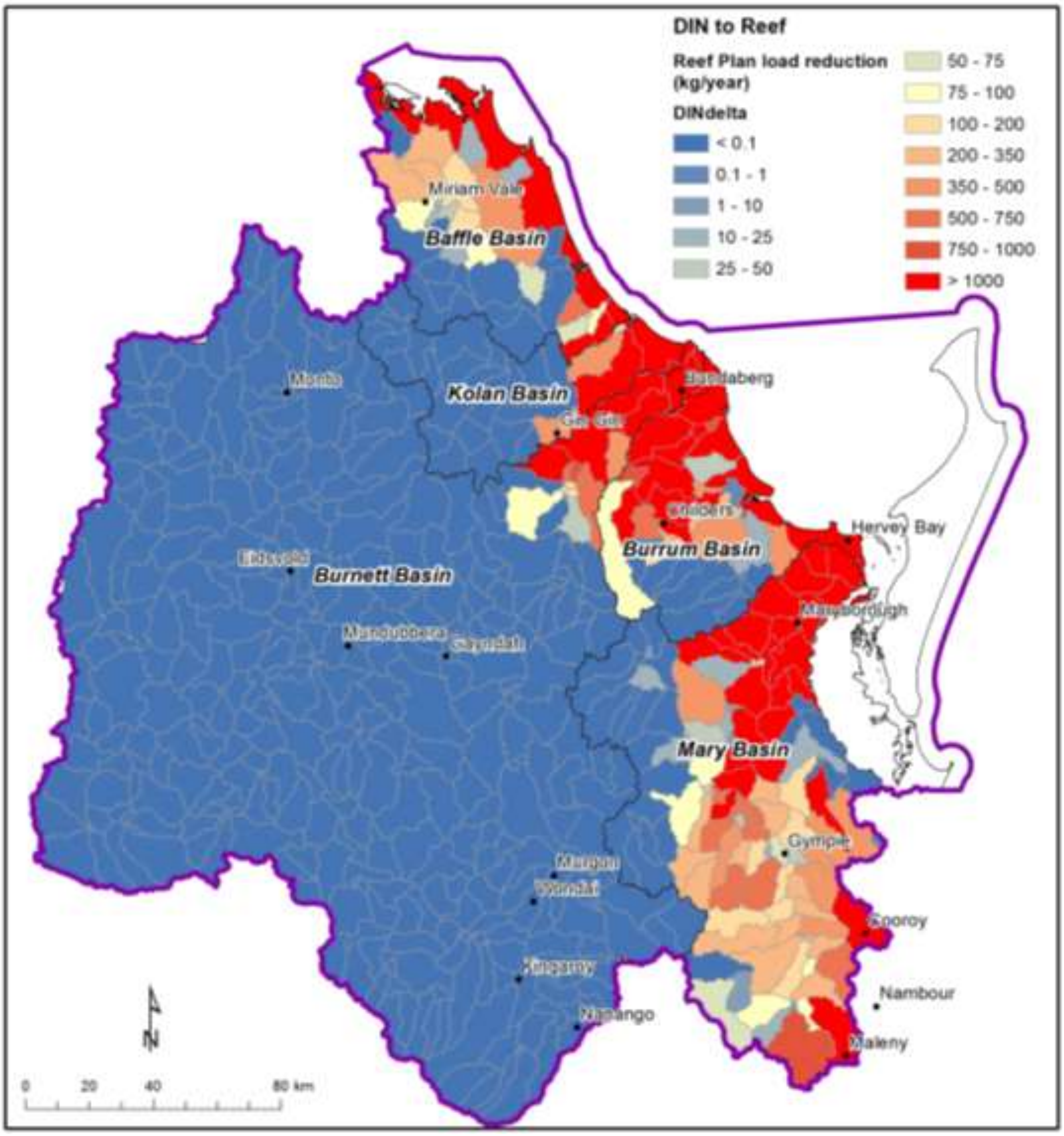


Figure 24 Reduction of DIN loads (kg/yr.) from the Burnett Mary region assuming full implementation of the WQIP to achieve Reef Plan targets.

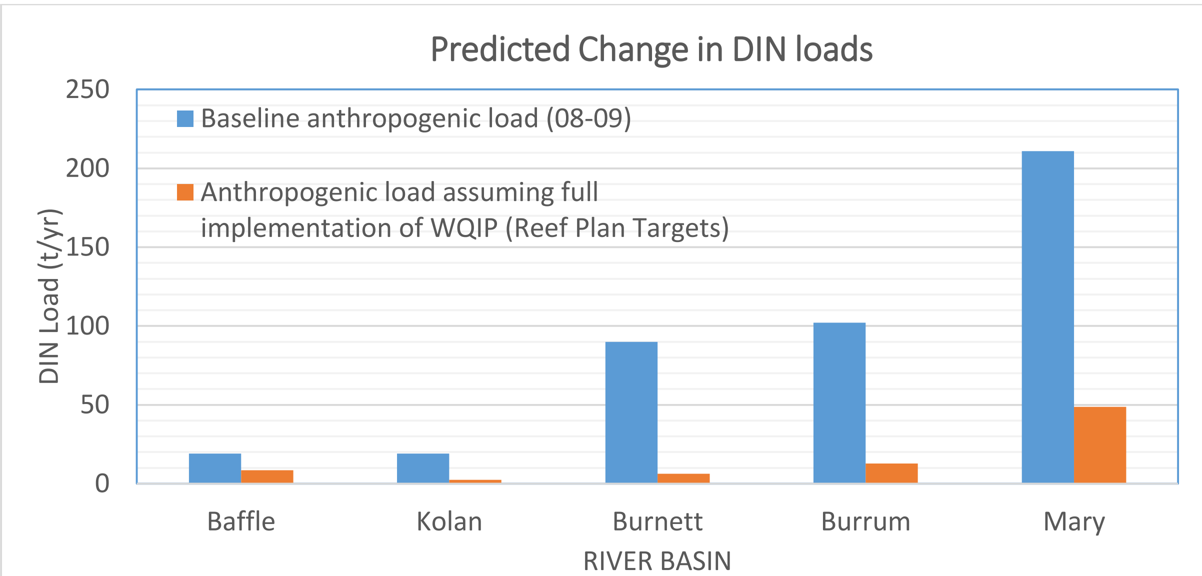


Figure 25 Predicted change in DIN load (t/yr.) assuming full implementation of the WQIP to achieve Reef Plan Targets

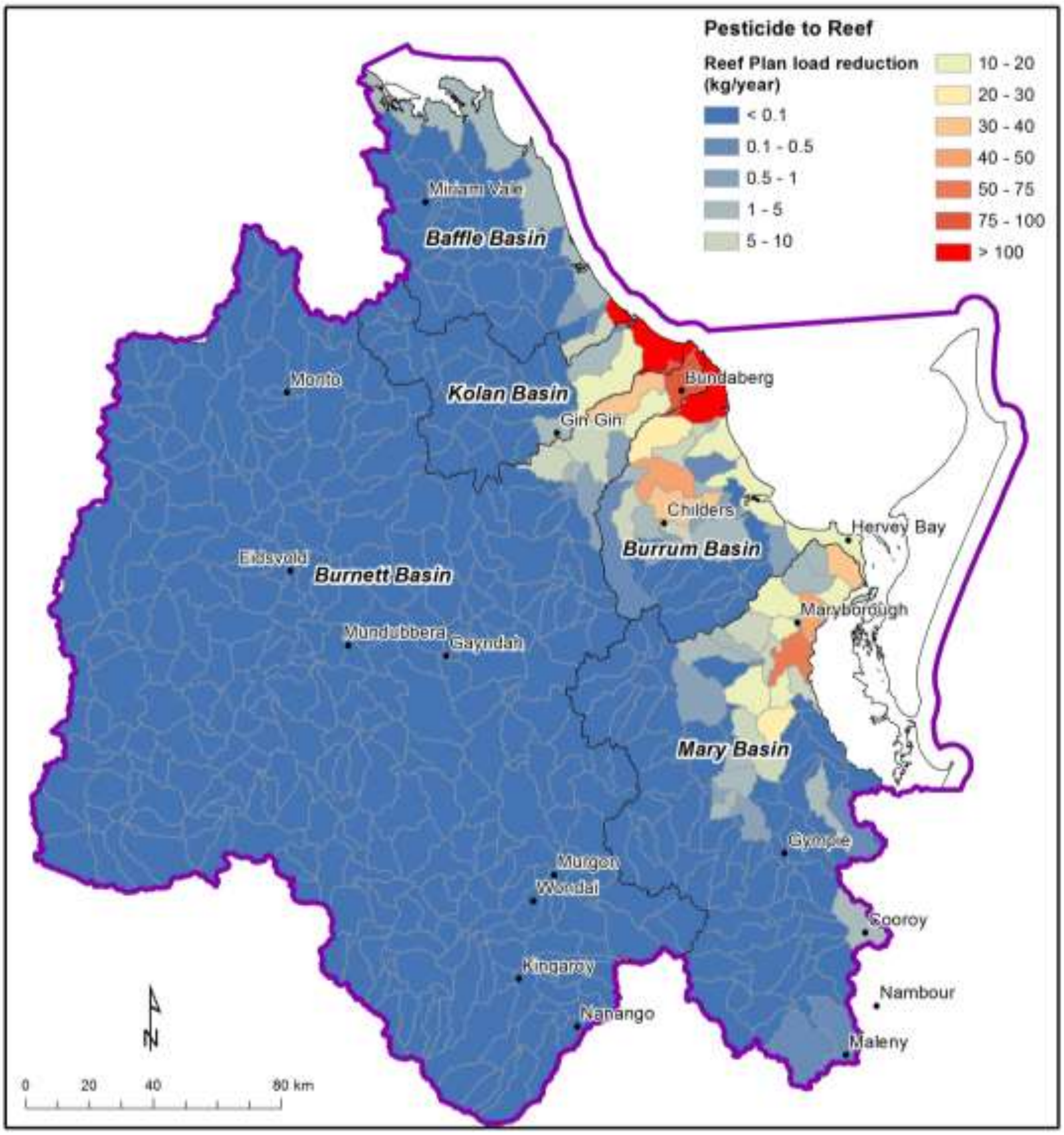


Figure 26 Reduction of PSII Herbicide loads (kg/yr.) from the Burnett Mary region assuming full implementation of the WQIP to achieve Reef Plan targets.

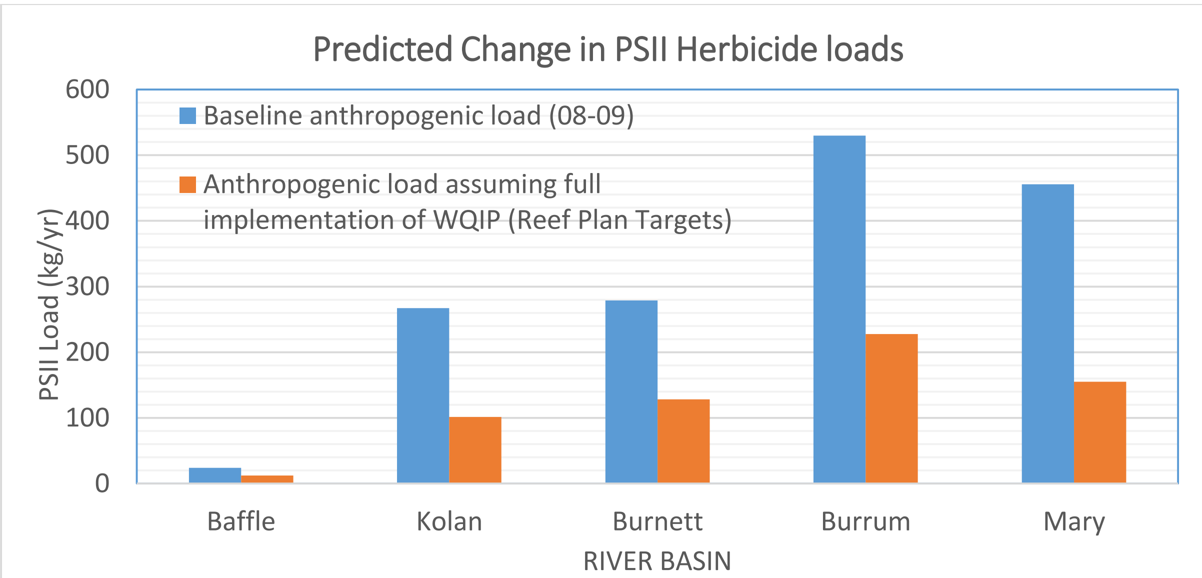


Figure 27 Predicted change in PSII load (kg/yr.) assuming full implementation of the WQIP to achieve Reef Plan Targets

Results are presented for TSS, DIN and pesticides, followed by a single figure of where net profit and loss is estimated.

8.4.1 Total suspended sediment

Very low levels of TSS load reductions are predicted to be required from the largest upper and middle Burnett catchment (Figure 22); this result occurs because of sediment trapping from dams which is captured in the Source Catchment model. A mosaic of sediment loss occurs from all basins within approximately 100 km of the Reef. Large areas in subcatchments close to the Reef, and particularly in the Mary catchment associated with cane and grazing land use require large reductions in sediment loads.

To meet RPTs the large changes in sediment loads are required from grazing subcatchments in the Mary catchment in particular. Both cane and grazing land uses are targeted for sediment load reduction – cane is targeted where other constituents can also be reduced and where practices are profitable, whereas sediment reduction in grazing always incurs a cost.

8.4.2 Dissolved Inorganic Nitrogen

Very large DIN loads are associated with sugar cane growing areas (Figure 24) in the lower Kolan, Burnett, Burrum (particularly Elliot and Gregory rivers) and the Mary catchments, including in some grazing areas. DIN load reductions are targeted largely to where the major DIN loads come from (Figure 25).

8.4.3 Pesticides

High pesticide loads come from major sugar cane growing subcatchments (Figure 26) with load reductions required to come from the same areas (Figure 27).

8.4.4 Net profit and loss associated with full implementation of Reef Plan Targets

Figure 28 shows the change in net profit (sum of profit and costs) associated with meeting RPTs. The figure shows that net profit can be achieved in sugarcane dominant areas (up to B practice)

Because of the large costs in grazing compared with cane, most of the grazing area is not targeted for the WQIP. Net profit is largely associated with sugarcane in the Kolan, lower Burnett and Burrum basins (Elliot and Gregory catchments in particular) and in selected other subcatchments. Large net losses occur in many subcatchments in the Mary and Baffle basins, because sediment reductions are required from grazing areas which are always estimated to incur a loss.

8.5 INFFER analysis on selected options and cost effectiveness

This section presents the Benefit:Cost analysis results of achieving the whole of region RPTs and ERTs using INFFER. It also presents a simple sensitivity analysis to show how reducing risks (such as lack of long-term funding, political risks) has large potential to increase the ratio of benefits to costs expressed as the Benefit:Cost Ratio (BCR).

The land use areas described in section 2 were used as the basis for assessment of the management practice changes required. The BCR parameters and results estimated for the RPTs and ERTs are summarised in Table 19.

Note that in addition to the direct net costs associated with practice change, the INFFER analysis also includes additional costs needed to run and administer the program of works and agency activities needed to achieve WQIP implementation.

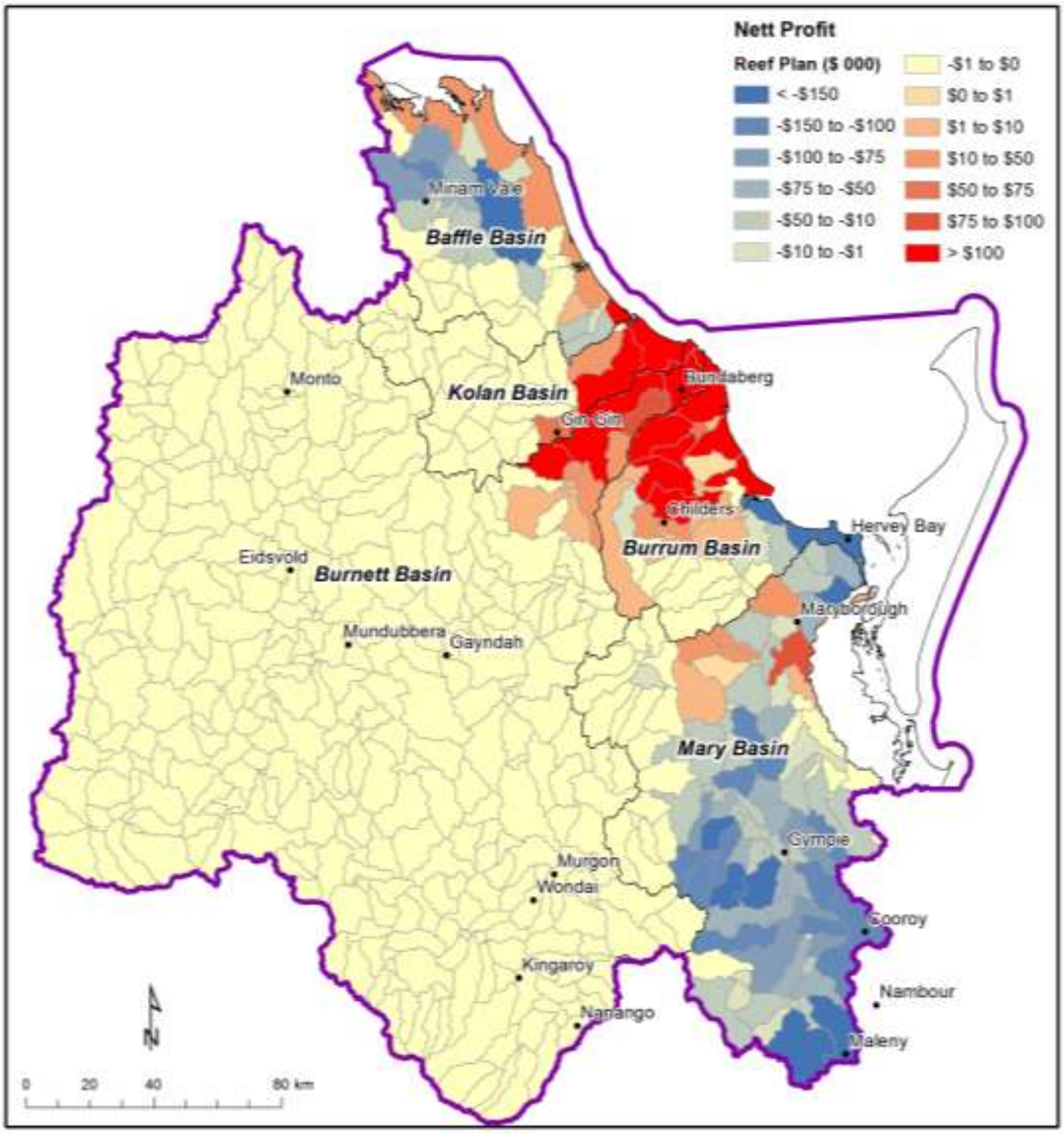


Figure 28 Net profit associated with Reef Plan targets from management practice changes required in in sugar cane and grazing land uses.

The two scenarios differ in terms of the scale of the nutrient and sediment reduction target, overall cost, and ultimate cost-effectiveness. Achieving the Ecologically Relevant Targets (ERTs) at a whole of region scale while feasible is very costly ($16.5m/year in direct works costs, namely $82.4 million over the initial 5 years, and additional indirect costs). This scenario requires extensive adoption of A practice management in both grazing and cane. To achieve practice adoption at the scale required, long-term ongoing incentive payments for sugar cane to achieve A practice (if B practices are profitable as suggested by government and industry then they should not require incentives for adoption). All grazing management actions are also likely to require incentives because all practices incur a net loss when non-financial barriers are accounted for. In addition to the large costs, the ERT scenario will be viewed as less acceptable from a socio-political perspective because industry is likely to object to the scale of adoption required of unproven A practices. The BCR for this scenario at 0.14 indicates that it is one-third the cost-effectiveness of the RPT scenario.

Table 19 Summarised INFFER results

Scenario with % load reduction estimated as achieved	Direct costs for works $M (over 5 years)	In-direct costs including program delivery and extension $M (over 5 years)	Total costs $M (over 5 years)	Maintenance costs $M/year (after 5 years)	Benefit: Cost Ratio (BCR)	BCR parameter values
Whole catchment RPTs (20% DIP*)	27.1	5.4	32.5	6.5	0.41	**V = 200, W = 0.10, L = 20, DFb (L) = 0.38, F = 0.87, A = 0.5, B = 1, P = 0.85 , C = 32.5, M = 6.5 , E = 0, G = 0.5**
Whole catchment ERTs (*20% DIP)	82.4	7.6	90	18	0.14	**V = 200, W = 0.17, L = 20, DFb (L) = 0.38, F = 0.87, A = 0.5, B = 1, P = 0.62, C = 90 , M = 18, E = 0, G = 0.3**

Meeting the RPTs has a BCR of 0.41. While this is still below the level where benefits exceed costs (score of greater than 1 needed to for a cost-effective project), this is not a bad result for a project of this scale and complexity when compared with other analyses conducted for large assets threatened by water quality such as the Gippsland Lakes (Roberts et al., 2012). It is also acknowledged that our estimation of Reef value might be conservative, if the Reef is valued 2.5 times the value we used, the BCR would be 1.

8.5.1 Sensitivity analysis of INFFER results

The BCR results are understandably sensitive to the parameters used. While the best available estimates and judgment has been used, there is uncertainty. To illustrate this, a basic sensitivity analysis was conducted by varying parameter values based on pessimistic, realistic (current values) and optimistic assessments for each of the RPT and ERT scenario (Table 20). Adjustment of values was restricted to factors including asset value, works effectiveness, technical feasibility, lag times, adoption and socio-political risks. Costs were unchanged for the sensitivity analysis as there is no basis for suggesting these would differ markedly from the base case costing already developed. The likelihood of future funding (G – long-term funding risk), rated as low for both pessimistic and realistic scenarios, has been assigned a value of 1 for the optimistic scenario.

Table 20 Benefit:Cost ratios for pessimistic, realistic and optimistic assessments for RPT and ERT scenarios

Scenario	Pessimistic	Realistic	Optimistic
2. RPTs whole region (20% DIP*)	0.07	0.41	2.12
4. ERTs whole region (*20% DIP)	0.02	0.14	0.90

Table 20 shows a range of BCRs, from extremely cost-ineffective to potentially cost-effective, (where a BCR score of 1 = cost-effective). The current political constraints (lack of guaranteed long-term funding and socio-political risks) are the major reasons for poor BCR values. If both of these risks were reduced then the BCR of the RPT scenario would increase to 0.55, while allocating the maximum values (optimistic scenario) for asset value, impact of works, technical feasibility and time lags increases the BCR to 2.12.

Challenges remain with the ERT scenario even when risks are reduced. Even the optimistic assessment of parameter values, where socio-political risk is adjusted to low and the likelihood of long-term funding is assured, the ERT scenario still appears not to be cost effective (BCR values less than 1). On current information achievement of ERTS is likely to require major and rapid innovation of alternative land management practices, or consideration of land use change, if cheaper than providing long-term incentives for BMPs. This latter option is likely to be the case.

The INFFER analysis supports the notion that the RPT scenario is more realistic and acceptable for the WQIP than the ERT scenario, albeit still very challenging to both government and industry. To achieve either RPTs or ERTs will require significantly increased levels of funding, beyond what is currently available, with the potential for significant and unacceptable impacts on agriculture than would currently be conceived.

9 Delivery mechanisms

For best-practice policies to be developed to address water quality, consideration of public and private net benefits is required. The public:private benefits framework was used to guide the development of policy responses for the WQIP and this represents a more strategic and quantifiable approach than has been used for previous programs.

Differentiated extension and incentive programs for the sugar cane and grazing industries will improve the effective use of government funding to achieve outcomes.

9.1 Public: private benefits and choice of appropriate policy tool

Implementation of the WQIP will require actions across a range of land uses including the range of agricultural landuses and urban areas, although the urban and horticultural impacts have not been able to be quantified. Targeted actions on agricultural land to improve water quality are required across all basins. 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), and
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).

9.2 Alternative policy options

Voluntary approaches involving extension and incentives dominate Australia's approach to trying to improve the environmental impacts from agricultural land use (Pannell & Roberts, 2010). While voluntary approaches are very important, consideration needs to be given to underpinning regulation as a component of best-practice policy.

International experience in developed countries such as the USA and New Zealand attempting to tackle eutrophication, shows that an important component of water quality policy includes regulation. This has also been recognized in Australia through Queensland's Great Barrier Reef Protection Amendment Act 2009, signalling the need for inclusion of a regulatory program for agricultural sources of water pollution and imposing a limited number of water quality improvement requirements on industry. The Act requires farmers in some regions (note that the Burnett Mary region is not within the regulated area) to calculate the optimal amount of nitrogen and phosphorus, keep more comprehensive records and fulfil conditions specified under the Act or operate pursuant to an accredited Environmental Risk Management Plan (State of Queensland 2009).

Commencement of a limited regulatory approach was a significant step in recognition that voluntary approaches alone are unlikely to be sufficient to protect the Great Barrier Reef. The bioeconomic modelling supporting this WQIP shows the very large scale of adoption required and the significant net costs this will cause for the sugar cane and grazing industries, providing further evidence to support that achieving voluntary adoption at the scale required to meet RPTs is extremely unlikely.

The development by Canegrowers of the SmartCane BMP approach involving industry self-assessment, industry certification on a five-year basis, industry auditing and random independent auditing (the details of which are as yet not clear) is a welcome industry initiative. Given the large scale land management changes required to achieve RPTs (and even greater changes if ERTs are needed to protect the Great Barrier Reef), the associated net costs (particularly the difficulties faced by small-medium sized farms) and accounting for non-financial adoption barriers, the evidence from this analysis and international experience in achieving nutrient load reductions of the magnitude required, points to the need for stronger engagement and recognition by both governments and industry that underpinning regulations in some form are likely to be required as a component of the policy response.

9.3 Comparison of INFFER results with current approaches used in the region

A range of programs have been used in the region to encourage adoption of practice change to reduce pollutant loads entering waterways and ultimately the marine ecosystems (see Table 21).

Current programs aim to achieve significantly less practice change than the results of bioeconomic modelling and INFFER indicate are needed to meet RPTs . Adoption of practice changes on cane and grazing land is required at a scale far greater than what can be achieved through current programs and funding levels. In current programs the level of practice change is not able to be linked to achievement of water quality targets and the bioeconomic modelling process used here explicitly links water quality targets to practice changes and costs.

Table 21 Current programs and delivery mechanisms

Program	Primary Delivery Mechanism	Details
Burnett Mary Reef Water Quality Grants and Partnerships Program	Extension – individual landholders Incentives	By 2016 will result in: • 6250 ha of grazing land managed with improved sediment management practices (1875 ha new, 4375 ha repeat grazing enterprises) • 4950 ha of sugarcane production land managed with improved nutrient and/ or pesticide management practices (1485 ha new, 3465 ha repeat cane growing enterprises) • 700 ha of horticulture production land managed with improved nutrient and/ or pesticide management practices (350 ha new, 350 ha repeat horticultural enterprises) • 200 ha of dairy production land managed with improved nutrient and/ or sediment management practices (60 ha new, 140 ha repeat dairy farming enterprises)
Better Catchments Program	Extension Demonstration sites	Priority activities include: • Grazing- soil testing for nutrients and acidity and rotational grazing and stocking intensity for improved groundcover. • Native Forestry- improved canopy cover (to increase light and photosynthesis for ground cover species) and stocking intensity to increase groundcover within native forestry stands. • Cropping- soil testing for nutrients and soil acidity, retention of crop residue and practice change from conventional cultivation to minimum till/ cultivation • Landholders adopting improved management practices through the provision of extension and workshops. Workshops will showcase overarching ideas and topics relevant to the target audience presented by respected experts. Extension will allow for landholders to receive information specifically relevant to their enterprise and be guided through the steps necessary to adopt new practices.
Sustainable grazing management and on-ground works: conserving soils in the Burnett Mary Region	Extension Incentives	Mitigation of significant gully and hill erosion in four locations covering 10 ha exacerbated by the 2013 Australia Day floods. These are in areas not covered by other current on farm flood recovery programs. Advice and support to landholders to adopt sustainable farming management practices over 10,000 ha to reduce the amount of sediment, nutrients and/or pesticides entering significant inland or coastal waterways. As part of Reef Plan implementation and a more productive move to promoting widespread best practice and less regulation of farmers, information being available on current use of pesticide

Program	Primary Delivery Mechanism	Details
		and fertiliser and the uptake of agricultural best management practice. This is a key measure to contribute to improved agricultural productivity and evaluating the success of broader practice changes in reducing the amount of sediment, nutrients and pesticides impacting on the GBR.
Grazing Best Management Practices	Extension	Advice and support to landholders to adopt sustainable grazing management practices over 40,000 ha to reduce the amount of sediment, nutrients and/or pesticides entering significant inland or coastal waterways.
Reef Program System Repairs: Better Banks for a Better Reef	Extension Incentives	Improve the condition and extent of biodiverse native habitats in the Baffle and Burrum/Tinana catchments to improve the quality of water entering the Great Barrier Reef lagoon. By June 2016, the program will have completed: • 18 ha of riparian revegetation • 56 km of riparian fencing • 30 workshops/field days • 110ha of weed management (Cats claw creeper, Madeira vine, Lantana, Rubber vine) • 2500 ha of feral pig control

Current programs are also not well targeted to priority catchments, nor have they attempted to link the ABCD practice framework best management efficiency estimates to the scale of change needed to achieve water quality targets.

Consideration of the costs of adoption, including the financial and non-financial barriers to adoption and the importance of farm size in practice adoption are also important elements that current programs have not been able to factor in. Considerable value has been added through work in this WQIP.

Overall current programs provide a useful basis to further develop programs and delivery models. The bioeconomic modelling and INFFER highlight that costs to achieve water quality targets will be much higher than current program funding levels, the scale of adoption needed is much greater and that adoption barriers are likely to be large impediments.

Financial viability issues for many grazing enterprises and for small and medium sized cane farms pose particular challenges for implementation required at the scale required to achieve load reduction targets.

10 Implementation programs

Implementation of the WQIP is based on achieving water quality targets through improving practices in grazing and sugar cane and fencing of waterways. While forestry, horticulture and urban areas are important, there is insufficient information to assess the costs and effectiveness of required practice changes.

The Mary catchment poses the highest risk to marine values, followed by the Burnett and Burrum catchments. The Kolan and Baffle catchments pose lower threats in term of water quality. Differential delivery mechanisms and a targeted approach to extension and incentives are required. Based on considerable international experience, underpinning regulations are likely to be an important component, but are not the focus of this WQIP.

The three main delivery mechanisms to recommended in this WQIP are: 1) Positive incentives in the form of long-term incentive payments, referred to as stewardship payments; 2) Extension will be required to accompany the provision of incentive payments and information transfer, and will require the development of clear and robust management agreements with landholders to ensure that mutual obligations are met over the long term; 3) Further research and development to fill knowledge gaps, particularly related to stream and gully erosion management.

To meet RPTs across the whole region, all sugar cane needs to move to A or B practice (9,400 ha cane to A practice level and 41,000 ha to B practice). Extensive changes are also required in the grazing industry – A practice management across 131,000 ha, from areas currently in B, C and D practices. Incentive programs and direct works in waterway fencing are also required, with most focus in the Mary catchment. There is a substantial need for additional research and development to better quantify waterway restoration hot spots, and for horticulture and urban impacts and potential for management.

Large areas of improved sugar cane management (A and B practice) are required – over 13,000 ha in the Burnett, close to 21,000 ha for Burrum, over 12,000 ha in the Mary, close to 10,000 ha in the Kolan and all of the small area of cane (less than 600 ha) in the Baffle catchment. Targeted work in grazing areas is estimated to be required in all catchments, but by the far the largest efforts are predicted in the Mary catchment – 24% of all grazing areas (116,000 ha) to be managed at A or B practice with additional areas of waterway and gully fencing. What appears certain is that extensive grazing management practice change is required to meet sediment targets – the relative emphasis on paddock, waterway and gully management is less certain; results are highly sensitive to the current modelling knowledge and assumptions used.

In addition to funding required for direct actions on land, enabling actions are required to conduct the WQIP implementation plan. This includes project leadership and management , monitoring, evaluation, compliance auditing associated with stewardship programs, reporting and additional research to better address major knowledge gaps.

This WQIP has a focus on achieving water quality targets in grazing and sugar cane and riparian management. While forestry, horticulture and urban areas are also important land uses there is much less information available on which to assess the costs and effectiveness of required practice changes. The modelling underpinning the WQIP assumes that water quality from other land uses will not change over the implementation period.

The implications of this is that management actions will be required on these land uses in order to prevent further increases in loads even though the scale of required practice change cannot yet be quantified. For example, new developments in urban areas are predicted to increase overall loads of sediments delivered to streams and expanding horticultural land uses have significant potential to increase nutrient loads.

The management actions identified in the implementation programs are estimated based on achieving the Reef Plan Targets at a whole of region scale. Actions have been selected based on modelled nutrient and herbicide loads from river basins, type of land use and the effectiveness and costs of management actions using a bioeconomic model which seeks to achieve an optimal solution for all constituents at least cost (or greatest profit).

It should be noted that for grazing all practice change shifts, whilst providing a positive public benefit, come at a cost to farmers. For sugar cane practice shifts up to B class practice are profitable in their own right, whereas A class practices come at a cost.

Implementation at the scale required to significantly reduce loads of nutrient, sediment and pesticides entering the Burnett Mary marine environment require differential delivery mechanisms and a targeted approach. Based on international experience, underpinning regulations are likely to be important component of water quality improvement programs, however in the current policy environment these are not focus of this WQIP. Given that B class practices have been assessed as profitable, it is possible that if extension programs do not achieve practice change to B class, regulation might need to be considered in future, particularly if landholders remain in D class practices.

The three main delivery mechanisms to be used within this WQIP are:

1) *Positive incentives: in the form of long-term incentive payments, referred to as stewardship payments.*
2) *Extension: It is important to note that the provision of incentive payments would also be underpinned by extension and information transfer, and will require the development of clear and robust management agreements with landholders to ensure that mutual obligations are met over the long term.*
3) *Further research and development: This is needed to fill knowledge gaps, particularly related to stream and gully erosion management.*

The implementation 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 the WQIP will require consultation and continued partnerships with the relevant industries are needed to help understand the reasoning and logic behind the changes to current approaches.

10.1 Overview of programs

Implementation programs for the Burnett WQIP include direct on-ground actions and enabling activities. The activities and implementation programs that need to be undertaken in order to meet the water quality targets are described below. Table 22 describes the programs and the approach for implementation. Tables 22-26 set out management outcome targets and activities required to meet the targets. The bioeconomic modelling results provide the link between the management outcomes and the water quality targets. A program of enabling actions is described in Table 28 which identifies the supporting activities required to ensure implementation of the WQIP.

Prioritisation of actions within each Basin has been informed by the results from the Water Quality Risk Assessment (Waterhouse et al. 2014). The results from the risk assessment identified the Mary as having the highest risk to marine values, followed by the Burnett and Burrum, with the Kolan and Baffle catchments having lower risk again. Knowledge gaps were identified as high priority (on the basis that there remain significant knowledge gaps).

Table 22 Overview of Implementation Programs for the Burnett Mary WQIP

Implementation Program	Management Actions / BMPs	Approach for delivery of programs
Sugar cane	**Incentive and extension programs to achieve adoption of improved practices as classified within the 'ABCD' framework.** This will require all cane to move to A or B practice (9,400 ha cane moves to A practice and 41,000 cane moves to B practice – activities in individual river basins shown in the following tables). Changes in the following practices will be required: Soil management and run-off • Crop residue cover – cane trash blanket • Controlled traffic • Land management during cane fallow • Tillage in plant cane • Tillage in ratoon cane Nutrient Management • Matching N supply to crop requirements • Timing of fertiliser application • Application method – subsurface or surface Herbicides • Timing of residual herbicide application • Targeting application to reduce volume • Residual herbicide use in ratoons Water management • Managing surface runoff • Optimising the irrigation system	Extension program to support shifts to B practice. Long-term incentive program to support shift to A practice. Development of long-term management agreements to support incentive delivery (until improved technology improves practices to become profitable in their own right). Auditing and reporting program to ensure compliance with management agreements.
Dryland Grazing	**Incentive and extension programs to achieve adoption of improved practices as classified within the 'ABCD' framework.** This will require change to A Practice across 131,000 ha of grazing land. Practice changes will be required from B, C and D practices. The practices changes require are: • Average stocking rates are consistent with district long term carrying capacity benchmarks for comparable land types, current land condition and level of property development • Retention of adequate pasture and groundcover at the end of the dry season (pasture assessment and stock management) • Strategies implemented to recover any land in poor or very poor condition	Incentive and extension program to support shift to A practice. Achieving transitions from D and C will also require significant support through extension and incentives. Development of long-term management agreements to support incentive delivery. Auditing and reporting program to ensure compliance with management agreements

Implementation Program	Management Actions / BMPs	Approach for delivery of programs
	• The condition of selectively grazed land types is effectively managed	
Waterways	**Incentive programs or direct riparian management works to support management of stock and encourage natural regeneration of indigenous vegetation.**	Direct works focused in the Mary basin, identification of hot spots in other Basins and areas of major sediment contribution. Further research and development is also required in the following areas: 1) improved information on the loads from stream and gully erosion, in particular the large discrepancy between loads estimated from geomorphology studies (Simon, 2014) and Source Catchments; 2) Improved identification of hotspots that can be feasibly managed particularly in the Mary catchment; 3) effectiveness of management strategies; 4) costs of fencing and livestock exclusion.
Horticulture	**Research and development to address knowledge gaps in terms of practices, practice effectiveness and costs.**	Given the intensity of horticulture, its potential for expansion and its proximity to the marine environment, better information is needed on specific costs and effectiveness of management practices to reduce water quality impacts. Given their importance, the focus should be on both macadamias and small row crops. Incentive programs if required should not be offered without information of the type that has been developed for the sugar cane and grazing industries.
Urban	**Adoption of improved practices in urban development. This includes:** • Stormwater management practices from development sites • Waste management • Marine debris (as a consequence of poor stormwater management) • Erosion and sediment control from development sites and council infrastructure projects • Urban transport (stormwater runoff from roads) • Pollution from Environmentally Relevant Activities. • Sewage treatment plant output management practices	Given the likely large costs associated with retrofitting, urban land practices will focus on new developments. The major issue is 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. The major implementation approach is to ensure pre-development design (Water Sensitive Urban Design), incorporates water quality improvement measures for post-development outcomes. Local government management is essential.

Implementation Program	Management Actions / BMPs	Approach for delivery of programs
	• Development Approval (DA) processing and conditions	
Enabling actions	• Oversight to implementation including; governance, monitoring evaluation and reporting and management of partnerships. • Project management of delivery of direct works and extension. • Communications and engagement • Investigations, research and monitoring.	In addition to direct works, a number of enabling actions are crucial in order to build on existing networks and the progress already made within the community. Oversight of the WQIP will be led by the BMRG. Implementation will require collaboration across natural resource management agencies, research organisations, government and community.

10.2 Direct works

10.2.1 Baffle Basin

Table 23 Baffle Basin Program

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Sugar cane	**100% of Sugar cane area (556 ha) in the Baffle is being managed within A and B practices.**	Incentive programs required to shift an estimated additional 143 ha to A practice and extension to shift 413 ha to B practice. No areas to remain under C or D class management.	BMRG Bundaberg Sugar Services	Medium
Dryland Grazing	**An additional 10% of the area of Dryland Grazing in the Baffle is being managed to A and B practice.**	Incentive programs to support dryland grazing practice shifts to A & B practices in selected subcatchments. The modelled practice shifts estimated to be required meet the deliverable are: an additional 7,154 ha in A practice and an additional 22,373 ha in B class. The shifts will be required from C class practices.	BMRG BCCA	Medium
Urban		Complete quantitative assessment of urban management practices. Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline.	BMRG and Gladstone Regional Council	High

10.2.2 Burnett Basin

Table 24 Burnett Basin Program

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Sugar cane	**100% of Sugar cane area (13,116 ha) in the Burnett is being managed within A and B practices.**	Incentive programs to achieve an estimated additional 696 ha to A practice and extension programs to achieve additional 10,980 ha in B practice. (The model predicts there to be no areas remaining under C or D class management in order to meet targets.)	Bundaberg Sugar Services	High
Dryland Grazing	**654 ha of the Dryland grazing land in the lower Burnett Basin is managed to A practice**	Incentive programs to support dryland grazing practice shift to A (an additional 654 ha in selected catchments in the lower Burnett) from B & C class.	BMRG BCCA	High
Horticulture		Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	Growcom	High
Urban		Complete quantitative assessment of urban management practices. Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline.	BMRG and Bundaberg Regional Council	High

10.2.3 Kolan Basin

Table 25 Kolan Basin Program

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Sugar cane	**100% of Sugar cane area (9,870 ha) in the Kolan is being managed within A and B practices.**	Incentive programs to support practice change in sugar cane areas. The model estimates an additional 1,405 ha under A practice. Extension programs to increase an additional 7,382 ha to B practice. (The model predicts there to be no areas remaining under C or D class management in order to meet targets.).	Bundaberg Sugar Services	Medium
Dryland Grazing	**Additional small areas of dryland grazing is managed within A and B practice**	Incentive programs to support dryland grazing practice shift to A and B. The model predicts an additional 40 ha to A practice and to increase 69ha in B practice. The shifts will be required from C class practices.	BMRG BCCA	Medium
Horticulture		Research and engagement with industry to assess costs and effectiveness of	Growcom	High

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
		management practices to reduce water quality impacts.		
Urban		Complete quantitative assessment of urban management practices. Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline.	BMRG	High

10.2.4 Burrum Basin

Table 26 Burrum Basin Program

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Sugar cane	**100% of Sugar cane area (20,961 ha) in the Burrum is being managed within A and B practices.**	Incentive programs to support practice change to A. The model predicts an additional 2271 ha in A practice. Extension programs to encourage practice change to B. The model predicts an additional 16,846 ha in B practice. (The model predicts there to be no areas remaining under C or D class management in order to meet targets.).	BMRG Bundaberg Sugar Services Isis Productivity Ltd	High
Dryland Grazing	**5%dryland grazing in the Burrum basin is managed within A practice**	Incentive programs required to shift dryland grazing to A from B & C class. The modelled practice change estimated to be required to meet the targets are: an additional 6,758 ha in A practice. The major shifts will be required from C (6,263 ha) followed by B (266ha) and D (228 ha) class practices.	BMRG BCCA	High
Horticulture		Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	Growcom BMRG	High
Urban		Complete quantitative assessment of urban management practices. Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline.	BMRG and Fraser Coast Regional Council	High

10.2.5 Mary Basin

Table 27 Mary Basin Program

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Sugar cane	**100% of Sugar cane area (12,584 ha) in the Mary is being managed within A and B practices.**	Incentive programs required to support practice change to A and B. The model predicts an additional 4,468 ha to A practice, and an additional 5,450 ha to B practice. (The model predicts there to be no areas remaining under C or D class management in order to meet targets.).	BMRG Maryborough CANEGROWERS	Very High
Dryland Grazing	**24% Dryland grazing in the Mary basin is managed within A class practice.**	Incentive programs required to support dryland grazing practice shift to A. The modelled practice shifts estimated to meet the targets are: an additional 116,000 ha in A practice. The major changes will be required from C (69,240ha) followed by B (34,645 ha), and D (12,857 ha) practices. Significant amounts of practice change are predicted to be required in the Mary catchment in order to achieve sediment reductions. The bioeconomic model is very sensitive to the cost and effectiveness assumptions used. It is possible that the balance between grazing land management and stream bank management is skewed as a result of the inputs. Until knowledge improves, flexibility and expert judgement should be used in the Mary catchment regarding the balance of investment between grazing and stream/gully management.	BMRG MRCCC	Very High
Waterways	**Riparian management[15].** **Research and development**	Incentive programs to supported uptake of riparian management (including fencing and regeneration of indigenous vegetation). Research and development: 1) improve information on the loads from stream and gully erosion, in particular the large discrepancy between loads estimated from erosion and geomorphology studies and Source Catchments; 2) Improved identification of hotspots that can be feasibly managed; 3) effectiveness of management strategies; 4) costs of fencing and livestock exclusion.	BMRG MRCCC DSITIA DNRM	Very High

[15] A target has not been set for this activity. The 16 km estimated from the bioeconomic model seems very low considering the importance of streambank erosion in the Mary catchment.

Implementation Program	Deliverable / Management Outcome Target	Management Actions / BMPs	Lead Agency and partners	Priority
Urban		Complete quantitative assessment of urban management practices. Identify management actions (current best practice or aspirational practice) required to (at a minimum) maintain loads from urban areas at 08-09 baseline.	BMRG, Fraser Coast and Gympie Regional Councils	High
Horticulture		Research and engagement with industry to assess costs and effectiveness of management practices to reduce water quality impacts.	BMRG Growcom	High

10.3 Enabling actions

Table 28 Enabling actions to support WQIP programs

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency and partners
Leadership	Overall responsibility for oversight of WQIP implementation Undertake mid-term review of the WQIP Undertake final review of the WQIP	0.4 FTE $68,000/year	BMRG
Governance	In partnership with the Australian government, Queensland Government and industry, will 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	BMRG Board
Project management and delivery and monitoring	Total of 6 full-time staff required, as specified below – one of whom can supervise overall project management in addition to incentive or extension delivery Cane – Based on approximately 9,400 ha cane required to be in A practice, and an average farm size of 125 ha, 1 full time position (servicing 75 farms) to design, implement and monitor the stewardship program is estimated. Cane – Extension staff to facilitate an increase of approximately 41,000 additional ha is required. Three extension staff are estimated each servicing approximately 110 growers (41,000/125 gives an estimated 330 growers) Grazing – based on approximately 130,000 ha grazing required to be in A class practice, and an average farm size of 880 ha, 2 full time full-time positions (servicing 75 farms to design, implement and monitor the program of stewardship payments program @ $170,000/FTE including expenses at least for the initial years.	$1,020,000/year[a]	BMRG and delivery partners

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency and partners
Communication	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 Signage	$40,000/year[a]	BMRG
Engagement	Develop a strategic engagement plan for the implementation of the Burnett Mary WQIP Develop annual engagement activity work plan 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	$50,000/year[a]	BMRG and delivery partners
Compliance and Auditing – stewardship payments	1 full time position to oversee compliance in both the cane and grazing industries. Farm visits and assessment of performance against management agreements for BMP implementation and stewardship payments It is important to have a person independent from the extension and incentive programs perform a proportion of landholder stewardship compliance assessments each year.	$170,000/year[a]	*Dependant on delivery mechanism
Investigations and planning – Urban	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.	$100,000/year	
Investigations and planning – Freshwater ecosystems	Complete prioritisation and action planning for freshwater ecosystems to inform funding (ie. for Systems Repai) drawing on available data and tools (AquaBAMM, BlueMaps, QSWAMP, Coastal ecosystem assessment framework, EVs and geomorphological studies)	$250,000[b]	BMRG, Australian Government, GBRMPA, Queensland government ,
Research to Fill Knowledge Gaps	Research and development: 1) improve information on the loads from stream and gully erosion, in particular the large discrepancy between loads estimated from geomorphology studies and Source Catchments; 2) Improved identification of hotspots that can be feasibly managed; 3) effectiveness of management	$200,000/year	Queensland government , CSIRO and/or universities

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency and partners
	strategies; 4) costs of fencing and livestock exclusion.		
Research to Fill Knowledge Gaps	Improved understanding of paddock to catchment scale processes to better predict understand relationships between nutrient, sediment and pesticide transport to waterways	$100,000/year	Queensland government
Research to Fill Knowledge Gaps	Improved understanding of the implications of predicted future climate change on catchment processes, water quality outcomes and ecological responses	$100,000/year	Queensland government , CSIRO and/or universities
Research to Fill Knowledge Gaps	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.	$200,000/year	Queensland government , CSIRO and/or universities

[a] These are costs for stewardship payments. To maintain benefits, stewardship payments require on-going annual payments.

[b] One off cost.

10.4 Monitoring, Evaluation and Reporting

The Burnett Mary WQIP describes the nature and scale of actions required to achieve specific nutrient, sediment and pesticide targets, within a given time frame (20 years) to protect and enhance the key values of the Great Barrier Reef, Great Sandy Strait and associated coastal ecosystems. Direct actions are largely focused on agricultural land through adoption of practice shifts and waterway fencing and gully remediation.

Monitoring and evaluation of the WQIP will focus on the following elements:

1. Enabling and engagement actions

- To what extent has knowledge and understanding improved?
- To what extent has this knowledge contributed to plan coordination, stakeholder engagement and practice change?
- Has new improved knowledge informed enabling and supporting actions?

2. Practice change

- What is the scale of uptake of the required practice changes and direct works by landholders and responsible agencies?
- What is happening to factors influencing adoption of these works, such as costs, knowledge and attitudes?

3. Effectiveness of actions

- What is happening to catchment loads of nutrients, sediments and pesticides as a result of the practice change?

4. Environmental outcomes

- What is the impact of reduced sediment, nutrient and pesticide inputs on the values (e.g extent and condition) of the key ecosystem components?

It is important to acknowledge that the activities that are the focus of the WQIP occur within a 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 addition, 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. Suggested monitoring activities are captured in Table 28.

Table 29 Monitoring activities (not captured in the research program) for Burnett-Mary WQIP

Monitoring activity	Frequency
End of catchment continuous water flow monitoring for priority catchments (at least) and all catchments	Continuous
In-situ water quality monitoring in priority catchments (including continuation of programs established in the Mary basin)	Bi monthly
Event based water quality monitoring in priority catchment	Event based
Marine water quality monitoring at key locations	Annual, and event based
Community water quality monitoring in priority catchments	Monthly, and event based
Collection of output data from on ground and engagement programs including spatial reporting of output data	Milestone and Annual reports
Stream flow monitoring for priority catchments	Continuous
Social benchmarking – capturing communities beliefs, perceptions, values, drivers, barriers and understanding of the asset condition and trends, and WQIP progress/achievements.	Every five years

Reporting and communicating the outcomes from the WQIP implementation is essential to ensure that the legacy of the Plan continues. Reporting activities have been identified in detail in the accompanying MERI Plan. In summary the key reporting mechanisms for the WQIP are:

- Catchment condition (focus on water quality against Reef Plan and Ecologically Relevant Targets) reporting every two years
- Implementation review summary every year
- Mid-term review
- Final review
- Reporting to funding bodies as required by their programs

10.4.1 Improvement

The WQIP Coordination/Implementation Group will oversee the implementation of the WQIP. It is also recommended that a Technical Panel take a strategic overview of the implementation of the Works Program ensuring continued reference to the program logic and development of conceptual understanding of the causal links between asset condition and trends, water quality and catchment impacts. The process for delivering against the plan will include regular structured meetings/ workshops to reflect on program, and what is, and is not working to improve delivery. In addition formal reviews will be held mid-way through (2017) and at the end of the implementation period (2020). The reviews will document:

- actual results against expectations,
- provide evidence of the management outcomes,
- assess the quality of information; and
- capture lessons learnt.

10.4.2 Key research activities

The Burnett Mary WQIP has been developed using the best available information. 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.

It is essential that the knowledge unpinning 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. Research priorities are presented in Table 30-Table 321.

Table 30 Ecosystem condition and trend research priorities

Major aim	Specific action	Review of previous studies
Improve understanding of the the response of key marine ecosystem components to poor water quality		(Thomas & Brodie 2014)
Seagrass condition and extent	Assessment of the distribution and condition of seagrass habitats across the whole Burnett Mary marine region	Coppo, C., Brodie, J., Butler, I., Mellors, J. and Sobtzick, S. 2014.
Coral reef condition and extent	Assessment of the distribution and condition of coral reef communities across the whole Burnett Mary marine region	As above
Coastal, estuarine and marine ecosystem assessments	Extend habitat assessments beyond coral reefs and seagrass to include wetlands, mangroves, estuaries and non-reef ecosystems.	As above

Table 31 Ecological Linkages Research Priorities

Major aim	Specific action	Review of previous studies
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 (which includes assessments of likelihood and consequence).	Risk Assessment - Waterhouse et al (2014)
Improve understanding of the relative risk to different asset areas and values	• Document extent/condition and trend of relationship between key assets and influences of respective river basins	
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 and Lewis 2014
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 and Great Sandy Strait

Table 32 Catchment Management Research Priorities

Major aim	Specific action	Review of previous studies
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	Andrew Simon – Burnett work Scott Wilkinson CSIRO work on gully and stream bank effectiveness and how applicable this is to the BM region. Review of assumptions in Source Catchments and P2R work for adequacy in assessing relationships between land management practices and water quality.
Improve and update the bioeconomic model	Review and update model to reflect improved understanding of: • Catchment modelling outputs and assumptions	No previous studies which explicitly link catchment targets to costs and load reduction have been conducted.

Major aim	Specific action	Review of previous studies
	• Economics across key contributing land uses/industries • Extent of adoption/disadoption of improved practices	
Capture of continuous improvement in best management practices for sugar cane, grazing, horticulture and forestry land uses	Review of BMPs and effectiveness estimates for all land uses – there will be limited data and so developing specific protocols to document and formally agree on best available BMP information is important – this is currently very informal.	Van Grieken et al (2014), Pannell et al (2014) Review of assumptions in P2R modelling regarding BMP effectiveness of ABCD practices. Review of practice adoption data currently collected.
Improve understanding of the current practice in horticulture industries (vegetable and tree crops)	Replicate approach used to assess sugar cane and grazing impacts for horticultural enterprises, including economic analysis of improved practice.	Few previous studies have been done. GrowCom could be more actively engaged to help identify what information might be available and QDAFF research and extension staff also. There will be a need for R&D if horticulture is to be better captured in terms of practice effectiveness.
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 BMWQIP. Urban efforts need to be able to be linked with agricultural sources through catchment modelling.

11 Burnett Mary in 2050

Nutrient, sediment and/or pesticide impacts are becoming more prevalent in many areas, and nowhere is the urgency and chance for reform most likely to occur in Australia than to protect the Great Barrier Reef. Investment in understanding impacts and assessing what needs to be done to reduce impacts has increased markedly in the past decade, and the ability to make informed investment decisions is much stronger than previously.

While many trajectories are possible, principles needed to maintaining some of the existing values of the marine ecosystems whilst makings best use of limited funding are: 1) Agreed performance goals/targets which means an agreed cap on total pollutant discharges; 2) Clearer rules, responsibilities and accountability of institutions; 3) Establishment of baseline nutrient discharges and development of appropriate metrics to enable industries (agricultural and urban) to respond to signals and funding opportunities; 4) Well considered and long term best practice policy approaches based on public and private net benefits and likely to require a mix of incentives, extension, research and underpinning regulations for different sectors; 5) Long term constructive commitment of government, industry and environmental stakeholders to understand perspectives, respect differences and work collaboratively.

Learning from international experiences, including the USA and New Zealand, along with and consideration of water trading schemes between agricultural and urban sources, will help Australia learn from other experiences and adapt approaches to suit the needs for our institutional, economic and environmental context.

Decline in water quality through eutrophication is rapidly becoming one of the world's most pressing concerns (Scholes & Ash 2005). Compared with water scarcity issues, water quality has received much less attention in Australia than in other developed regions, the USA and Europe in particular. This is understandable given Australia's relative low population density and short agricultural history compared with other developed regions. Worldwide, and in Australia, agricultural impacts remain the major challenge to addressing water quality problems worldwide (Roberts & Craig 2014).

While Australia now has major eutrophication problems in all states, what happens on the Great Barrier Reef is likely to influence the water quality policy agenda nationally and internationally. This is because of its outstanding national and international values. It is largely unquestioned as Australia's greatest natural asset, as well as one of the seven wonders of the natural world (http://www.unmuseum.org/7wonders/greatreef.htm).

There is the opportunity to project the future trajectory of the Burnett Mary portion of the Reef and Great Sandy Strait in 2050. 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 & Selman, 2012; Roberts & 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:

- The Great Barrier Reef 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 and Great Sandy Strait 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 for Queensland and Australia 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;
- Partnerships with industry and significantly increased public funding are crucial as much of the action needs to occur on private land. It is likely that private benefits from water quality investment will remain negative across most industries and geographic areas for the foreseeable future, therefore achieving public good outcomes will need to acknowledge this reality. Research and development of improved technologies (equivalent to A class or better) which are adoptable at scale are critical;
- Given Australia's need to compete in a global economy as well as the economy of scale challenges faced by smaller farmers, the trend towards intensification and/or increasing farm size in 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, and the relativity of sources between hillslope, gully and stream bank erosion still have a relatively low level of confidence;
- 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, commitment to improving the science (especially integration with economics), taking action now whilst managing adaptively, and investing in an increasingly strategic and targeted fashion will be required if agricultural impacts on the marine ecosystems of the Burnett Mary are to be managed.

While many trajectories are possible, the following principles are likely to be needed to maintaining some of the existing values of the marine ecosystems through reducing agricultural and urban 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. We draw on New Zealand, USA and our Australian experience in particular and suggest that the following factors need to have been addressed if the Reef is to be protected as well as possible by 2050.

Principles needed:

- Performance goals/targets which means an agreed cap on total pollutant discharges
- Clear rules, responsibilities and accountability of institutions
- Establishment of baseline nutrient discharges and development of appropriate metrics to enable industries (agricultural and urban) to respond to 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 constructive commitment of government, industry and environmental stakeholders to understand perspectives, respect differences and work collaboratively

From the perspective of protecting some of the World Heritage values of the Great Barrier Reef from agricultural and urban sources the vision for 2050, not restricted to the Burnett Mary region, is that there will be well established and agreed:

- Ecologically meaningful caps/limits on pollutant discharges for major constituents across major contributing land uses, including urban sources.
- 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 Reef, and Australia's experience in developing trading schemes (eg water markets) make water quality trading seem a sensible approach to explore and learn from the experience of others (eg Lake Taupo in New Zealand). International lessons from trading include that trading is very promising but is challenging thing to get to work in practice. Trading schemes need to be well designed, build on lessons learned from others internationally and recognise that success require times, resources and high-level expertise.
- 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 Environmental Protection Agency[16]
- Research (development of improved technologies and long-term commitment to modelling) and monitoring programs to gauge progress and manage adaptively.

An incremental largely business as usual approach will not address the challenges facing the Great Barrier Reef.

[16] Although regulation is unpopular, inadequate or poorly enforced water quality regulations are the biggest hurdles to establishing robust water quality trading markets (Greenhalgh & Selman 2012)

12 Reasonable assurance statement

This WQIP was developed using available published and unpublished information, technical expertise and local knowledge. Where significant knowledge gaps and uncertainties exist, assumptions have been stated or acknowledged where there was insufficient information on which to make decisions. Aspects of the WQIP should be updated as part of an adaptive management process of learning and review as knowledge improves.

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 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, 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.

12.1.1 Values

Overall value of the Burnett Mary portion of the Great Barrier Reef plus Mary catchment receiving waters – Low uncertainty. There has been a limited amount of work to date done assessing the values of the Great Barrier Reef. (Thomas & Brodie 2014) have apportioned Reef wide information into values for the Burnett Mary region. While there is likely to be considerable uncertainty and contestability in any value put on the Great Barrier Reef itself and any portion thereof, the international significance of the Reef is undisputed. Furthermore sensitivity analysis on the asset value has been conducted within the INFFER analysis. Value is only one of a series of parameters that may impact on benefit:cost analysis.

12.1.2 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. The main threats are agricultural 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., 2013)

12.1.3 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 due to limited validation of the remote sensing data, 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.

12.1.4 Targets

Water quality load reduction targets – Medium uncertainty. Reef Plan Targets have been available since 2009 and Ecologically Relevant targets have been much more recently developed (Brodie and Lewis 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.

12.1.5 Economic analysis

Limited economic analysis of the sugarcane and grazing industries has been conducted in the Burnett Mary region. The WQIP built on and augmented previous economic analysis. Reports for sugarcane (van Grieken et al. 2014) and grazing (Pannell et al. 2014) are available. The explanation for ratings for major sources of uncertainty are outlined in Appendix 2 in Park et al. (2014).

Farm heterogeneity - Low-Medium uncertainty. Some heterogeneity has been captured in size and costs. The coarseness of scale in Source Catchments modelling has meant that we had to artificially separate loads to beyond where we are comfortable.

Profitability and costs - Low-Medium uncertainty. We used best available local expertise and built on available work conducted in other regions. The coarseness of scale in Source Catchments is likely to be a larger issue than the economics.

12.1.6 Bio-economic modelling

The construction of the bioeconomic model was particularly ambitious, and required integration of paddock and catchment modelling as well as the economic work outlined above. There were two main groups of uncertainty – the model construct itself and the model inputs. The ratings for uncertainty factors are outlined in Park et al. (2014), Appendix 2. Overall the model construct has been peer-reviewed by a leading international water quality bioeconomic modelling expert and assessed as sound (report by Graeme Doole available on request).

12.1.7 Challenges with the model construct

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 very limited data to test management practice effectiveness and we are suspicious of very high load reductions from C-B practice in particular. This might be due to aspiration as much as evidence.

Stream loads and lengths – Moderate uncertainty. There are large discrepancies between modelled loads and geomorphology work.

Model constraints – Medium uncertainty. People are unlikely to have informed views about how much to constrain the model and are prepared to accept output results unless they look odd (which they have done when the model has been constrained at different times in response to discussions).

12.1.8 Challenges with the model inputs

Effectiveness of practices themselves –Moderate uncertainty. There is limited field data on practice effectiveness.

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 sugarcane 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.

12.1.9 Benefit:cost analysis

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.

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Appendix

Appendix 1: Additional legislation and conventions context for the Burnett Mary WQIP

WQIPs have had a focus on receiving waters, i.e. the Great Barrier Reef and Great Sandy Strait. The principal legislation relating to protection and management of the Reef 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 Reef. 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
- 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.

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
- Fisheries Act 1994
- Local Government Act 1993

- Marine Parks Act 2004
- Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004
- Marine Parks (Great Sandy) Zoning Plan 2006
- 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, 1992Convention 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 (Ramsar), 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: Estimation of value (V) in the INFFER analysis

In order to assess the benefits of protecting the Great Barrier Reef through works proposed in this WQIP, it was important to estimate its value as part of the INFFER analysis. Somewhat surprisingly, despite all the work that has been done on the Great Barrier Reef region there has been very limited work on assessing the value of the Reef itself.

Both market values and non-market values were used to inform the INFFER analysis. To enable the market valuation to be completed for the WQIP, Deloitte Access Economics data was used as the basis and some additional simple assumptions were made.

In their study Deloitte Access Economics estimated the financial benefits generated by the GBR region at $5.68 billion per annum. Of this, 92% is attributed to tourism, and most of the rest to commercial fishing and recreation. These benefits include indirect benefits (multiplier effect) representing flow-on effects to the rest of the economy. These benefits include tourists who visit anywhere in the GBR marine park or adjacent catchment area.

To estimate the Reef-specific value, the value assessed from the Deloitte study was adjusted to account for the following factors:

- Only 15.8% of tourists who come to the region actually visit the Reef (based on the equivalent Access Economics study for 2006-7).
- Of the tourists who visit the Reef, it is assumed that 25% would come to the region anyway, even in the absence of the Reef. It seems reasonable to assume that the percentage would be at least that high, given that 84% of tourists in the regions don’t visit the Reef.
- It is assumed that, on average, Reef tourists spend the same amount in total as tourists to the region who don’t visit the Reef.

Given these assumptions, the financial benefits from tourism attributable to the Reef are $613 million per year. These are combined with other financial benefits (calculated as value added) as follows.

Tourism	$613 million
Commercial fishing	$160 million
Recreation	$244 million
Science and management	$98 million
Total	**$1,115 million**

Valuation of the Reef also needs to include non-market values. The Deloitte Access Economics study did not include these, only the immediate market considerations. Non-market values include less tangible values that cannot be estimated from assessing financial benefits alone. Environmental assets cannot simply be valued in terms of the financial benefits they generate.

Updated figures were generated for this project (Pannell, 2014).Using a study of the non-market values for environmental improvements in Queensland (Windle and Rolfe 2006) as an approximate guide, estimates of non-market values were subjectively estimated as $10 per person per year, equating to a present value of $193 over 50 years for every person in Australia (at the time 22.7 million). This gives a total non-market value of $227 million per year. Of course there is high uncertainty about this value and as new information becomes available this can be used to refine the value estimate for the Reef.

Combining both benefits (financial and non-market) gives a total benefit attributable to the GBR of $1,342 million per year.

Taking a present value over 50 years using a real discount rate of 5% gives a total value of $25,800 million, or $26 billion.

Converting this to a *V* score for use in INFFER gives *V* = 1,300 (Pannell, 2014). This value was subsequently used to determine the relative value of the Burnett Mary region, according to three alternative methods described below.

As outlined above we have assumed an overall GBR value of 1300 (equivalent to a total present value of $26 billion). For this WQIP we need to assign a value to the Burnett Mary potion of the GBR with additional consideration to the seagrass and coral located in the Great Sandy Straits. Thomas & Brodie (2014) explored four contrasting approaches to determine the regional economic values of the Great Barrier Reef;

1. Regions are valued as equal fractions of the Great Barrier Reef value.

2. Regions are valued proportional to their total asset area (reef, seagrass and coastal wetland).

3. Regions are valued proportional to the market value of the commercial activities (tourism, commercial fishing and recreation) that they support.

4. Regions are valued proportional to their contribution to the market value of commercial activities, and their contribution to total asset area expressed as a function of total monetary non-market value (i.e., a combination of 2 and 3).

The four approaches outlined above yield different results when calibrated against the INFFER value for the GBR of 1300. The results are summarised in Table below.

Table 1 Results of different approaches to determination of INFFER value (V) score for the Burnett-Mary region

Approach	INFFER V score
1. Value divided equally between regions	217
2. Value relative to asset area	156
3. Value derived from market value of commercial activities	238
4. Value derive from a combination of market value of commercial activities and non-market values	235

The results above highlight that while the different valuation approaches yield a range of values for estimating the INFFER value the differences are not that significant, especially when considered in relation to all other factors included in the overall analysis of benefits and costs. Approach 4 was deemed to be the most robust of the different methods and a score of V = 235 ($ value equivalent of

$4.7 billion for Burnett Mary component of the Great Barrier Reef) has been used for the INFFER analysis, while the upper (V = 238) and lower (V=156) bounds have been explored through a sensitivity analysis.

Appendix 3: Priority Management Mapping

The GBRMPA Priority Management Mapping[1] provides a framework for identifying priority hydrological connections that support coastal ecosystems providing important value and function to the Great Barrier Reef World Heritage Area (World Heritage Area), based on the outcomes of the Informing the Outlook for Great Barrier Reef coastal ecosystems Report[2]. One of the outcomes from developing the framework is to develop a tool to assist in providing more certainty to State and Local Governments and the private sector to assist with investment decisions in housing, infrastructure and natural resource development in growth regions regarding priority Great Barrier Reef coastal ecosystems for protection, remediation and management. The framework takes a 'whole of landscape' view that can be used to guide future development, identifying those areas in the catchment that are important because of their hydrological connection to the Great Barrier Reef World Heritage Area.

The framework developed is based on bringing together and analysing existing Queensland Government datasets (such as floodplain and wetland mapping, erosive landzones, highest astronomical tide and vegetation mapping). The output is a 'blue map' identifying areas within the Great Barrier Reef catchment, which are hydrologically connected to and deliver important ecological functions for the World Heritage Area. The framework has been piloted for a management case study in the Baffle basin[3] and developed for the remaining basins in the Burnett Mary Region.

Development and ongoing management of coastal ecosystems in the Great Barrier Reef catchment for agriculture, urban areas, industrial use and the required supporting infrastructure (roads, rail etc.) has the potential to alter spatial configuration of ecosystems at a landscape scale. This change causes habitat fragmentation which can damage or destroy the function and connectivity of ecosystems to the World Heritage Area. Modification of coastal ecosystems for residential or industrial development can potentially break this connectivity not only through the direct removal of habitat but also through changes to hydrological connections, and the resulting quality and quantity of water entering the World Heritage Area. The legacy of past land use change remains an issue in the Great Barrier Reef catchment, in particular in the coastal zone and floodplain where historically development approvals have been granted even if no development has yet taken place. Some of these 'approvals' pre-date environmental legislation.

The map layers used to develop the 'blue map' are pre-existing map layers available from the Queensland Government. These layers can be incorporated into regional and local planning to guide future development, while identifying how to best protect ecological values and facilitate management decisions that promote the improvement in the health and resilience of the values of the inshore Great Barrier Reef World Heritage Area.

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[1] Great Barrier Reef Marine Park Authority, Scoping a framework to identify priority areas that support the Great Barrier Reef world heritage area. 2013.

[2] Great Barrier Reef Marine Park Authority, Informing the outlook for the Great Barrier Reef coastal ecosystems. Townsville, Qld.: Great Barrier Reef Marine Park Authority, 2012.

[3] Great Barrier Reef Marine Park Authority, Baffle basin assessment: Burnett-Mary Regional Management Group Natural Resource Management region : assessment of ecosystem services within the Baffle Basin focusing on understanding and improving the health and resilience of the Great Barrier Reef. 2013.

Scope and develop a framework to identify priorities for protection, rehabilitation and management of coastal ecosystem areas that connect the landscape and deliver ecological function to the World Heritage Area.

13.1.1 Methodology

The conceptual diagram of the 'blue map' framework (Figure 4) is based on a compilation of existing natural area and natural hazard mapping, and identifies where coastal ecosystems, connections and functions retain their highest value (priority protection) or have been modified to varying degrees (need rehabilitation, restoration and management)

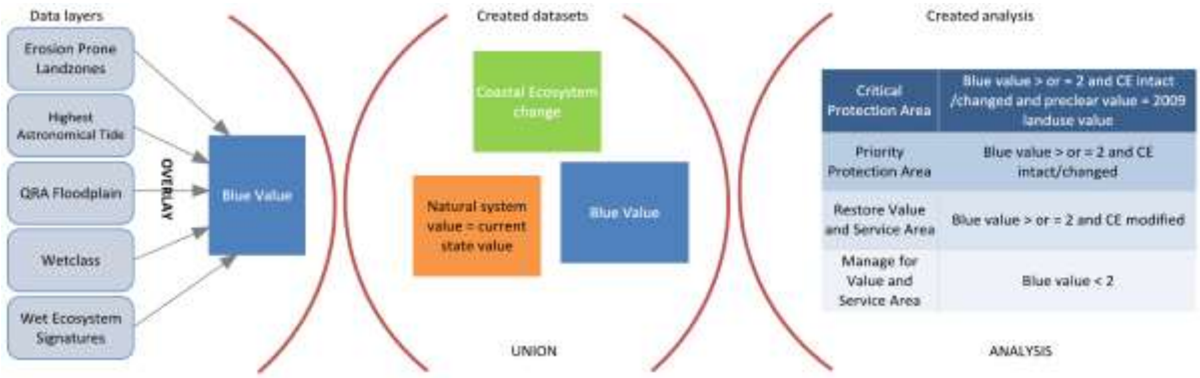

Figure A3.1. Conceptual diagram of the components used to develop the 'blue map' framework.

Baffle Basin Blue Map

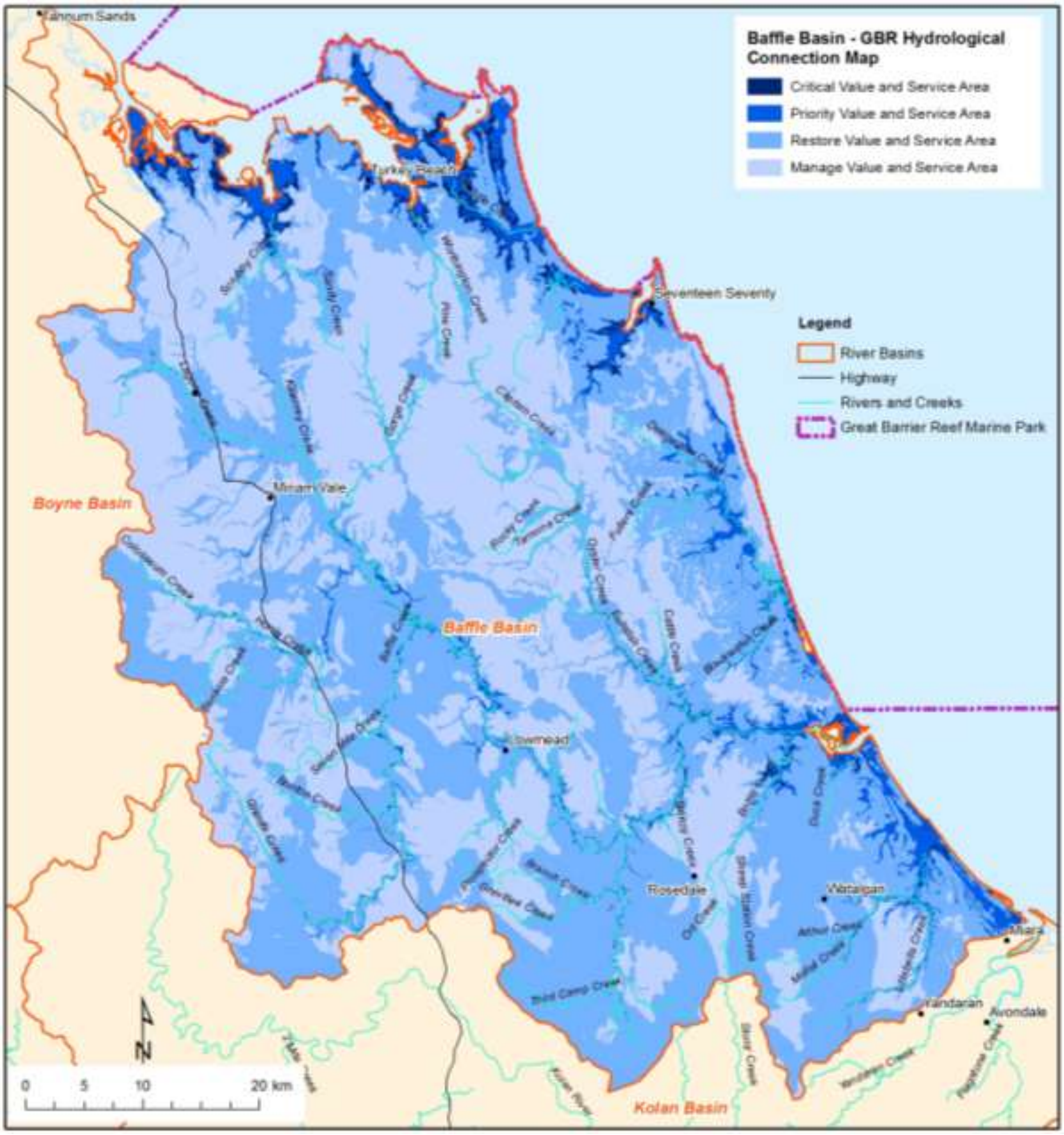

Figure A3.2: Hydrological connections and areas of priority for ecological function to the World Heritage Area in the Baffle basin

Burnett Basin Blue Map

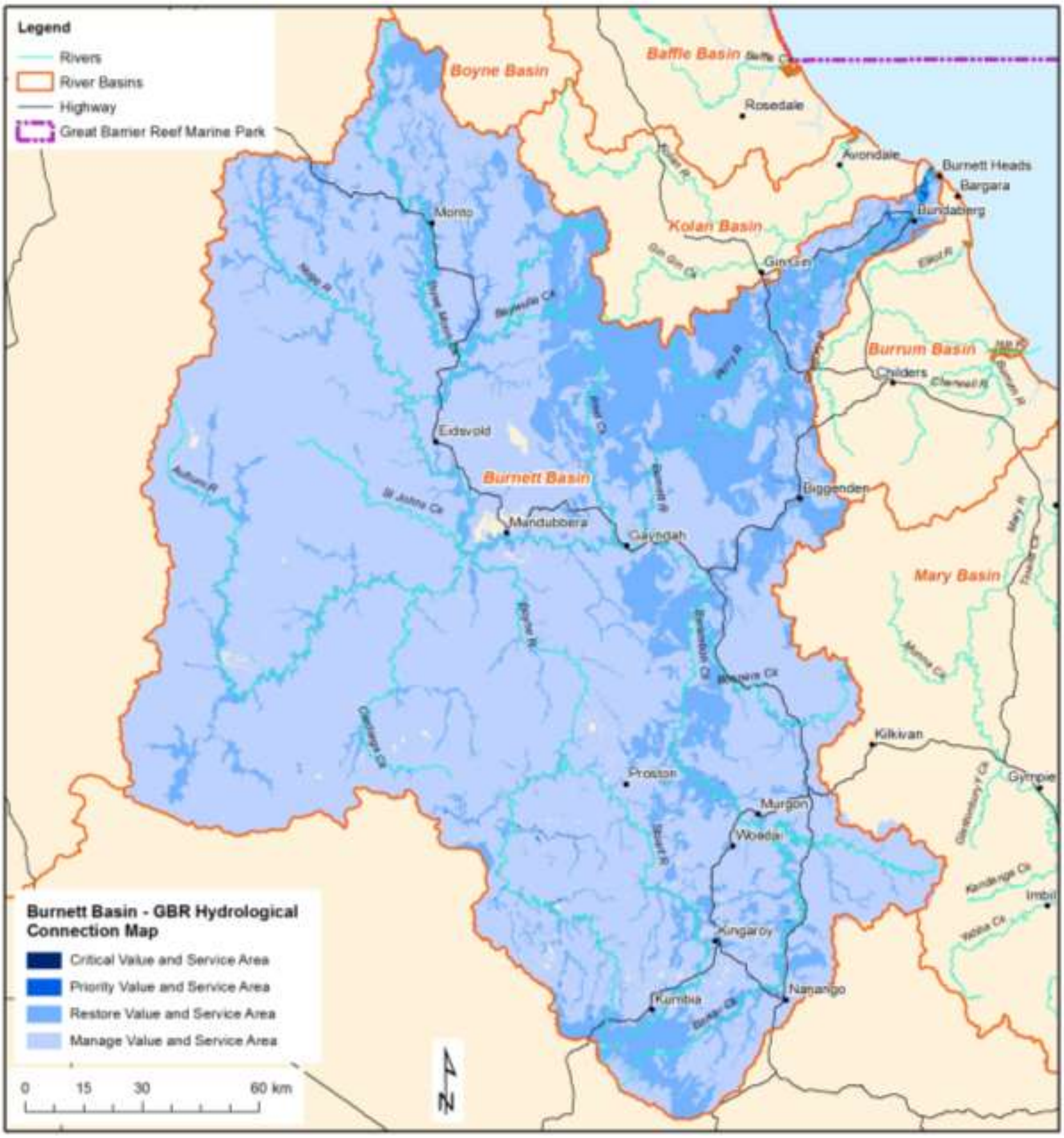

Figure A3.3: Hydrological connections and areas of priority for ecological function to the World Heritage Area in the Burnett basin

Burrum Basin Blue Map

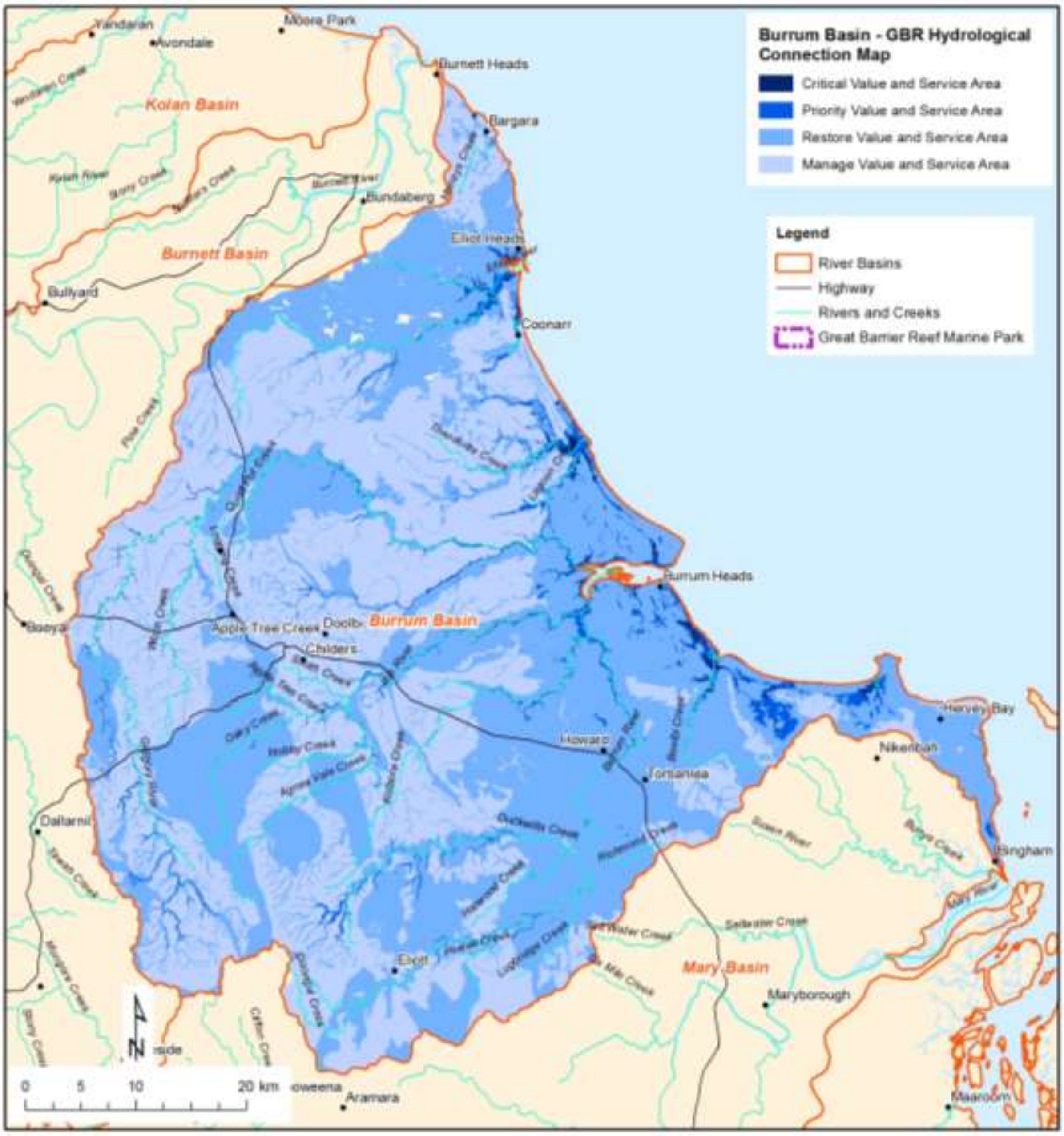

Figure A3.4: Hydrological connections and areas of priority for ecological function to the World Heritage Area in the Burrum basin

Kolan Basin Blue Map

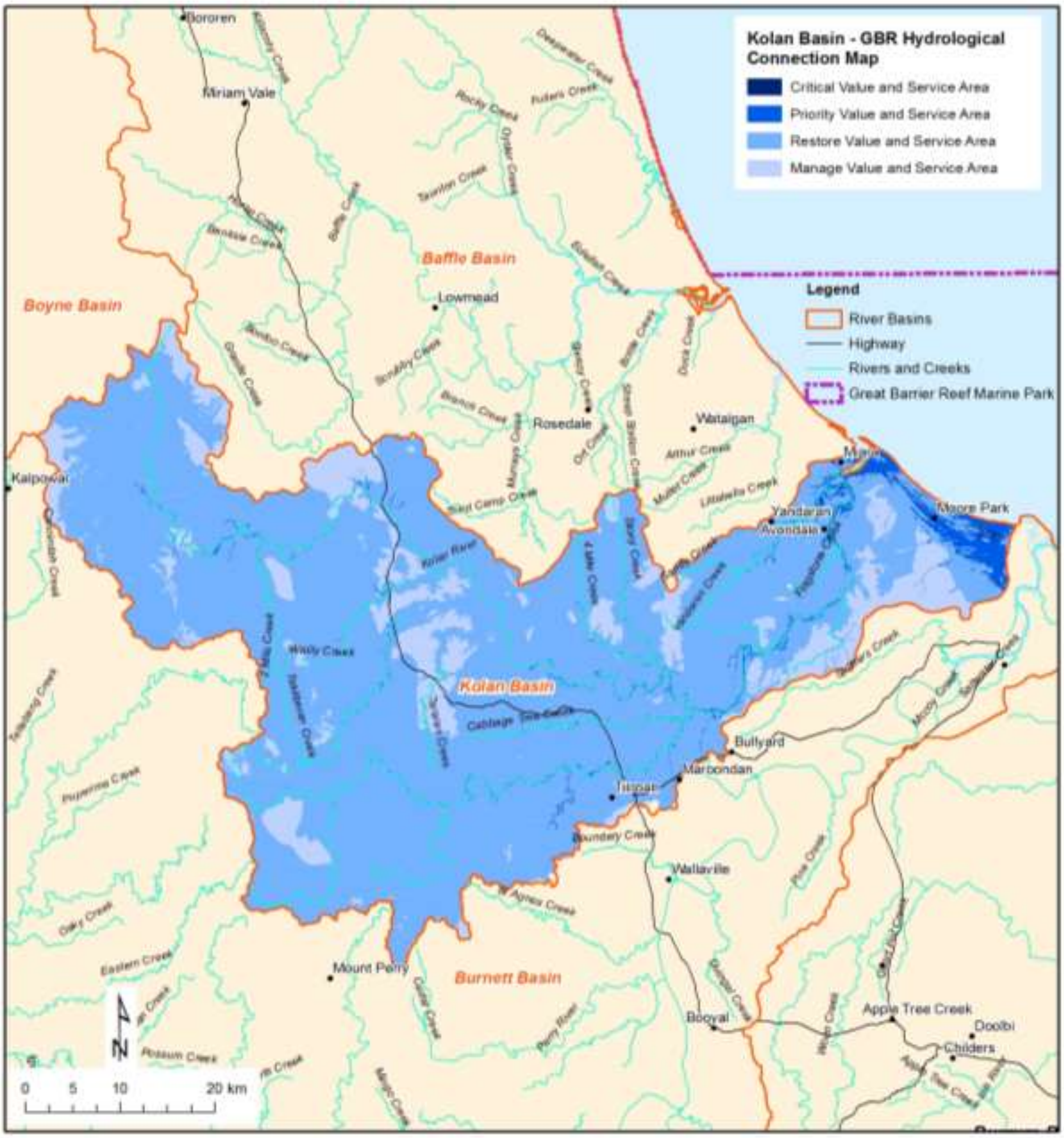

Figure A3.5: Hydrological connections and areas of priority for ecological function to the World Heritage Area in the Kolan basin

Mary Basin Blue Map

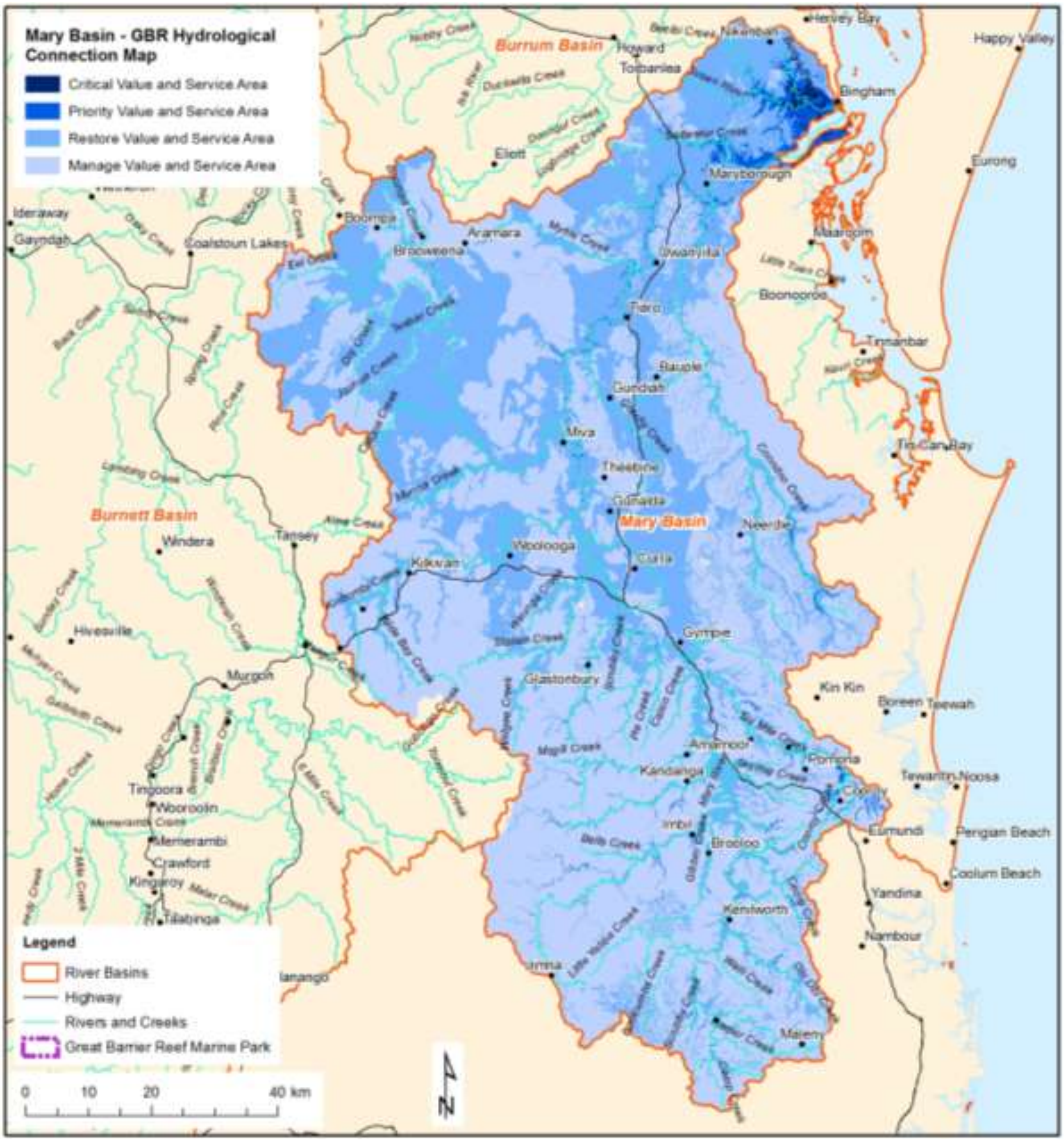

Figure A3.6: Hydrological connections and areas of priority for ecological function to the Marine Area in the Mary basin

Appendix 4 : A proposed Urban ABCD Management Practice Framework

Introduction

In 2010, Reef Catchments convened the Urban Think Tank as an initiative of the Healthy Waterways Alliance Mackay Whitsunday Isaac. The Think Tank was tasked with examining urban impacts on waterways and developing management strategies to improve waterway health in and around urban centres.

In response, the Urban Think Tank has designed an Urban ABCD Management Framework that aligns with the agriculture industry frameworks.

The Urban ABCD Framework is designed as a mechanism to rate management practices within urban centres and their likely impacts on waterway health. Impacts may be from nutrients, chemicals, sediment or solid waste. Subsequent impacts on waterway health from activities in urban centres are ranked relative to best management practice standards.

The Structure of the Framework

Urban centres have been identified as the 'management unit' – similar to a large scale agricultural land holding unit.

The urban centre management unit may be comprised of:

- New development
- Revitalised development
- Roads
- Commercial, industrial and residential land use
- Waste management
- Sewerage treatment works

Each urban centre management unit can be broken down into components which represent good practice and good outcomes, or poor practice and poor outcomes. For the purpose of this framework, the components of the management unit are known as themes.

The urban centre themes that may influence the quality of water leaving an urban management unit are identified in the Urban ABCD Management Framework as follows:

- Stormwater management practices from development sites
- Waste management
- Marine debris (as a consequence of poor stormwater management)
- Erosion and sediment control (ESC) from development sites
- Erosion and sediment control (ESC) from Council infrastructure projects
- Urban transport (stormwater runoff from roads)
- Pollution from Environmentally Relevant Activities (ERAs)
- Sewage treatment plant output management practices
- Development Approval (DA) processing and conditions
- Energy
- Water conservation measures
- Open space management
- Development on floodplain areas

Activities and/or outcomes for each urban centre theme are defined for:

A class (aspirational)

B class (best practice)

C class (conventional practice meeting minimum standards)

D class (poor or dated practice)

These four management standard classes are designed to indicate the range of actions that reflect poor practice through to practices that meet minimum requirements, best management practices, culminating in innovative practices.

An urban centre is assessed against the urban centre themes and management standard classes (A, B, C, or D) to determine whether the practices used in that area are producing outcomes that minimise impacts on nearby waterways. Scores are assigned to the theme on a sliding scale with A scoring the highest, D scoring the lowest.

Urban centre themes have been weighted to reflect the relative impact each will have on the waterways.

Theme Weighting Definition:

Theme weightings are a probabilistic weighting that reflects the relative potential impact or likelihood of significant impact on water quality from an activity. Some activities are more likely to have significant impact on water quality depending upon the level of management practice (A, B, C, or D) adopted in undertaking the activity. 1 reflects the lowest relative potential impact activity and 3 represents the highest relative potential impact activity.

Scores for an urban centre are totalled and ranked against the rating table to assign an overall score for the urban centre. An excel spread sheet has been developed to readily record scores and ranking for quick reference of raw scores or comparison between urban centres reflected as a percentage.

The urban centre themes and ABCD management standard class definitions

The following pages outline the Urban Centre Themes with their corresponding Management Standard Class definitions for activities and/or outcomes.

Stormwater management practices from development sites

Theme Weighting = 1

Dated Storm Water Management Plan	Conventional Urban Storm Water Management (Greenfield developments)
• No Council Storm Water Management Plan. • Basic stormwater infrastructure designed. • No Water Sensitive Urban Design (WSUD) incorporated into developments or Council projects. • No Council landscaping strategy or Plan. • No Council Policy on Erosion and Sediment Control Plan.	• Council Storm Water Management Plan being developed. • Basic stormwater infrastructure designed. • No or little Water Sensitive Urban Design (WSUD) incorporated into developments or Council projects. • Council landscaping strategy or Plan being developed. • Council Policy on Erosion and Sediment Control Plan being developed.
Best Practice Urban Stormwater Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban Stormwater Management (Greenfield developments)** **Innovative practices that require further validation**
• Council Storm Water Management Plan finalised. • Stormwater infrastructure designed to reflect BMP. • Water Sensitive Urban Design (WSUD) considered in development design and incorporated into developments or Council projects. • Council landscaping strategy or Plan finalised. • Council Policy on Erosion and Sediment Control Plan finalised.	• Council Storm Water Management Plan implemented. • Stormwater infrastructure designed according to BMP and being implemented. • Water Sensitive Urban Design (WSUD) incorporated into developments or Council projects. • Council landscaping strategy or Plan implemented. • Council Policy on Erosion and Sediment Control Plan implemented.

Waste management

Theme Weighting = 1

Dated Urban Waste Management	Conventional Urban Waste Management
• No Council waste management strategy or plan. • No Recycling strategy. • No Landfill operation plan. • No Council Litter Management strategy.	• Council waste management strategy or plan under development. • Recycling strategy under development. • Landfill operation plan under development. • Council Litter Management strategy under development.
Best Practice Urban Waste Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Waste Management** **Innovative practices that require further validation**
• Council waste management strategy or plan finalised. • Recycling strategy finalised. • Landfill operation plan finalised. • Council Litter Management strategy finalised.	• Council waste management strategy or plan implemented. • Recycling strategy implemented • Landfill operation plan implemented. • Council Litter Management strategy implemented.

Marine debris (as a consequence of poor stormwater management)

Theme Weighting = 1

Dated Marine Debris Management **Management practices that are superseded or unacceptable**	**Conventional Marine Debris Management** **Management practices that meet minimum expectations**
• No marine debris programs developed. • Clean up Australia day program planned by community group and restricted to operating at one location. • Council slow to react to storm generated debris on foreshores – response time more than 2 weeks. • Lack of formal arrangements in place to clean up marine debris.	• A basic marine debris program developed by Council or a community group. • Marine debris included in a basic Council waste plan as an issue. • Clean up Australia day program planned by community group and restricted to operating at 1 – 5 locations. • Council slow to react to storm generated debris on foreshores – response time more than 1 week. • Basic arrangements in place to clean up marine debris which includes defined roles in the Council. • Some Gross pollutant traps installed but not necessarily in strategic locations and having poor maintenance programs.
Best Practice Marine Debris Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Marine Debris Management** **Innovative practices that require further validation**
• An integrated marine debris program where the community work with the Council. • Marine debris included in Litter management plan. • Marine debris funded as part of Council/community waste management strategy. • Marine debris data collected. • Council quick to react to storm generated debris on foreshores – response time less than 1 week. • Formal arrangements in place to clean up marine debris which includes defined roles in the Council, state government and community. • Stormwater management plan developed which aims to collect gross pollutants from urban areas. • Education and awareness program developed to reduce marine debris. • Clean up Australia day program planned by community group and restricted to operating at 1 – 5 locations and on more than one accession a year. • Development and implementation of integrated litter management strategies that incorporate the Marine Debris Threat Abatement Plan (TAP) (DEWHA 2009) actions. (To address key threatening process 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (EPBC Act 1999) • Develop clean marine strategy to implement current best practice in coastal marinas.	• Marine debris data collected and used to influence mainland stormwater management and marine users. • Marine debris included in Litter management plan. • Comprehensive marine debris program which is linked to urban stormwater planning and retail outlets. • Council quick to react to storm generated debris on foreshores – response time less than 2 days. • Formal arrangements in place to clean up marine debris which includes defined roles in the Council, state government and community. • Stormwater management plan developed which aims to collect gross pollutants and chemical pollutants from urban areas. • Clean up Australia day program planned by community group and restricted to operating at 6 – 20 locations and on more than one accession a year. • Marine debris collection program funded via a number of sources including the private sector. • Education and awareness program developed to reduce marine debris and integrated into schools and commercial activities. • Adopt clean marine strategy to implement current best practice in coastal marinas.

Erosion and sediment control (ESC) from development sites

Theme Weighting = 2

Dated ESC Management Management practices that are superseded or unacceptable	Conventional ESC Management Management practices that meet minimum expectations
• No enforcement of ESC conditions on developments. • Erosion and sediment control goals and effective possible measures not included in Council development manual. • No community and industry education programs for ESC associated with development. • Council staff not trained in ESC. • No Council procedures on how to develop ESC plans for development sites. • No ESC incorporated in Council works. • No measurement of ESC measure outcomes from development sites.	• Basic inspections conducted on ESC conditions on developments. • Erosion and sediment control goals and effective possible measures included in Council development manual. • Basic community and industry education programs for ESC associated with development. Use of leaflets. • Council outdoor staff given basic training in ESC, Council planning and compliance staff given basic training in ESC. • Council procedures on how to develop ESC plans for development sites. • ESC incorporated in Council works – basic 1 page plans for each site showing general measures that will be used. • No measurement of ESC measure outcomes from development sites.
Best Practice ESC Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational ESC Management** **Innovative practices that require further validation**
• Audits conducted on ESC conditions on developments. • Erosion and sediment control goals and effective possible measures included in Council development manual. Conditions for various developments listed. • Integrated community and industry education programs for ESC associated with development. Use of leaflets, education and awareness programs, demonstration sites. • Council outdoor staff given extensive training (5 day workshop) in ESC, Council planning and compliance staff given extensive training (5 day workshop) in ESC. • Council procedures on how to develop ESC plans for development sites highly developed. • ESC incorporated in Council works – basic 1 page plans for each site showing general measures that will be used, plus ESC strategy. • Measurement of ESC measure outcomes from development sites via water quality measurements.	• Audits conducted on ESC conditions on developments. • Erosion and sediment control goals and effective possible measures included in Council development manual. Conditions for various developments listed. • Integrated community and industry education programs for ESC associated with development. Use of leaflets, education and awareness programs, demonstration sites. • Council outdoor staff given extensive training (5 day workshop) in ESC, Council planning and compliance staff given extensive training (5 day workshop) in ESC. • Council procedures on how to develop ESC plans for development sites highly developed. • ESC incorporated in Council works – basic 1 page plans for each site showing general measures that will be used, plus ESC strategy. • Measurement of ESC measure outcomes from development sites via water quality measurements.

Erosion and sediment control (ECS) from Council infrastructure projects

Theme Weighting = 1

<table>
<tr><th>Dated ESC Management

Management practices that are superseded or unacceptable</th><th>Conventional ESC Management

Management practices that meet minimum expectations</th></tr>
<tr><td>• No road work or drainage engineering plans issued before work commences.
• No erosion or sediment control plans.
• No Environmental Management Plans.
• No pre-start meetings.
• No community consultation.
• No budget estimates for work.
• Project timeline and milestones not calculated
• No site rehabilitation plan.</td><td>• Basic road work or drainage engineering plans issued before work commences.
• No erosion or sediment control plans.
• No Environmental Management Plans.
• Some communication between construction crews and engineers prior to work commencing.
• No community consultation.
• Budget estimated for work.
• Project timeline and milestones known but not recorded.
• No site rehabilitation plan.</td></tr>
<tr><th>Best Practice Infrastructure Development ESC/EMP Management

Currently promoted Best Management Practices (BMPs)</th><th>Aspirational Infrastructure Development ESC/EMP Management

Innovative practices that require further validation</th></tr>
<tr><td>• Road work or drainage engineering plans issued before work commences.
• Water sensitive urban design principles incorporated into design plans.
• Erosion or sediment control plans for site developed.
• Environmental Management Plans for site developed.
• Communication between construction crews and engineers prior to work commencing. Other Council staff such as environmental section informed of work.
• Community consultation – notice in newspapers.
• Budget calculated for various sections of the work.
• Project timeline and milestones recorded and plotted.
• Site rehabilitation plan developed.</td><td>• Road work and drainage plans issued before work commences.
• Water sensitive urban design principles incorporated into design plans. Innovative solutions developed and implemented.
• Erosion or sediment control plans and report produced for the staged development.
• Appropriate Environmental Management Plans developed
• Communication between construction crews, engineers and other Council staff prior to work commencing.
• Community consultation undertaken when considered important.
• Accurate budget forecasted and reported.
• Project timeline and milestones recorded.
• Comprehensive site rehabilitation plan.</td></tr>
</table>

Urban transport (stormwater runoff from roads)

Theme Weighting = 2

Dated Urban Transport Management Management practices that are superseded or unacceptable	Conventional Urban Transport Management Management practices that meet minimum expectations
• No transport infrastructure plan. • No public transport service. • Traffic congestion at a number of locations in central business area. • No urban plan to reduce reliance on cars. • Inefficient transport network causes inefficient transport of people causing high amounts of fuel to be used short transport distances. More than 5km of transport route where the average fuel consumption is >20L/100km for a 4 cylinder vehicle. • Road system does not have the capacity to collect, store and treat polluted stormwater runoff.	• Basic transport infrastructure plan showing primary, secondary and tertiary carriage ways, speed limits, and traffic lights. Some basic information on traffic volumes recorded using manual traffic counts, but also automatic recording devices. • Basic public transport service underutilised. • Traffic congestion at a number of locations in central business area. • No urban plan to reduce reliance on cars. • Inefficient transport network causes inefficient transport of people causing high amounts of fuel to be used short transport distances. 3-5km of transport route where the average fuel consumption is >15L/100km for a 4 cylinder vehicle. • Road system has a basic capacity to collect, store and treat polluted stormwater runoff. This is mainly via grassed swales designed to trap sediment.
Best Practice Urban Transport Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban Transport Management** **Innovative practices that require further validation**
• Transport infrastructure plan showing primary, secondary and tertiary carriage ways, speed limits, and traffic lights. Information on traffic volumes recorded using manual traffic counts, but also automatic recording devices. Future modelled using computer software used to plan future roads for the next 5 years. • Appropriate public transport service, fully utilised. • Traffic congestion at a number of locations in central business area, but only during peak commute periods. • Urban plan to reduce reliance on cars, for example use of bikes. • Transport network has few examples of inefficient transport areas causing high amounts of fuel to be used short transport distances. • Road system has a reasonable capacity to collect, store and treat polluted stormwater runoff. This is mainly via grassed swales designed to trap sediment, but also use of stormwater filter systems (eg Stormwater 360 modules).	• Transport infrastructure plan showing primary, secondary and tertiary carriage ways, speed limits, and traffic lights. Information on traffic volumes recorded using manual traffic counts, but also automatic recording devices. Future modelled using computer software used to plan future roads for the next 30 years. • Appropriate public transport service, fully utilised. • Traffic congestion at a small number of locations in central business area, but only during peak commute periods. • Urban plan to reduce reliance on cars, for example use of bikes. • Transport network has few examples of inefficient transport areas causing high amounts of fuel to be used short transport distances. • Road system has a reasonable capacity to collect, store and treat polluted stormwater runoff. This is mainly via grassed swales. designed to trap sediment, but also use of stormwater filter systems (eg Stormwater 360 modules).

Pollution from Environmentally Relevant Activities (ERA's)

Theme Weighting = 1

Dated Urban ERA's and Pollution Management **Management practices that are superseded or unacceptable**	**Conventional Urban ERA's and Pollution Management** **Management practices that meet minimum expectations**
• No inspections of ERAs by the Council or DERM. • No compliance of stormwater or sewerage discharges by ERA. • No interception devices used between workshop and sewerage system. • No interception device between the ERA workspaces and the nearest waterway. • No interception device for air borne pollutions.	• Annual inspections of ERAs by the Council or DERM. • Basic compliance of stormwater or sewerage discharges by ERAs – complaint initiated. • Basic interception devices used between workshop and sewerage system. This may be a single box trap. • No interception device between the ERA workspaces and the nearest waterway. • No interception device for air borne pollutions. Choose paints or chemicals chosen which have a lower emission hazard.
Best Practice Urban ERA's and **Pollution Management** **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban ERA's and** **Pollution Management** **Innovative practices that require further validation**
• Annual inspections of ERAs by the Council or DERM. • Basic compliance of stormwater or sewerage discharges by ERA – complaint initiated. • Basic interception devices used between workshop and sewerage system. This may be a single box trap. • No interception device between the ERA workspaces and the nearest waterway. • No interception device for air borne pollution. Choose paints or chemicals chosen which have a lower emission hazard.	• Inspections of ERAs by the Council or DERM only where required to maintain compliance or to demonstrate above compliance measures for licensing discounts • All ERA's compliant with minimising stormwater and sewerage discharges. • Sophisticated and effective interception devices used between workshop and sewerage system. • Sophisticated and effective device between the ERA workspaces and the nearest waterway. • Sophisticated and effective device for air borne pollution.

Sewerage treatment plant output management practices

Theme Weighting = 3

Dated Sewerage Treatment Plant Output Management **Management practices that are superseded or unacceptable**	**Conventional Sewerage Treatment Plant Output Management** **Management practices that meet minimum expectations**
Planning: • Hydraulic load capability – hydraulic load exceeds plant capability by more than 30% (Average dry weather flow). • Nutrient outputs – TN more than 10 times ANZECC guidelines for tropical freshwater systems. • No telemetric system to monitor discharge rates • No automatic water quality loggers. • No annual operational plan for the STP. • No planned upgrade or replacement plan. • Basic maintenance program. • Basic understanding of the cost of operating the STP.	Planning: • Hydraulic load capability – hydraulic load exceeds plant capability by 10- 30% (Average dry weather flow). • Nutrient outputs – TN more than 5-10 times ANZECC guidelines for tropical freshwater systems. • Basic telemetric system to monitor discharge rates. • Water samples taken manually and analysed - no automatic water quality loggers. • Basic annual operational plan for the STP. • Components of the STP identified for upgrade or future replacement – no planned upgrade or replacement plan. • Adequate maintenance program. • Basic understanding of the cost of operating the STP.
Best Practice Sewerage Treatment Plant Output Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Sewerage Treatment Plant Output Management** **Innovative practices that require further validation**
Planning: • Hydraulic load capability – hydraulic load 80-100% of plant capability (Average dry weather flow). • Nutrient outputs – TN more than 3- 5 times ANZECC guidelines for tropical freshwater systems. • Telemetric system to monitor discharge rates and manipulate sections of the STP process. • Water samples selected and analysed by automatic water quality loggers. • Comprehensive annual operational plan for the STP. • Detailed STP upgrade and replacement plan - components of the STP identified for upgrade or future replacement. • Adequate maintenance program. • The cost of the STP is well known.	Planning: • Hydraulic load capability – hydraulic load 80-100% of plant capability (Average dry weather flow). • Nutrient outputs – TN more than 3- 5 times ANZECC guidelines for tropical freshwater systems. • Telemetric system to monitor discharge rates and manipulate sections of the STP process. • Water samples selected and analysed by automatic water quality loggers. • Comprehensive annual operational plan for the STP. • Detailed STP upgrade and replacement plan - components of the STP identified for upgrade or future replacement. • Adequate maintenance program. • The cost of every component of the STP is well known. Depreciation established and future infrastructure replacement fund establishment.

Development Approval (DA) processing and conditions

Theme Weighting = 1

<table>
<tr>
<th>Dated DA approval processes

Management practices that are superseded or unacceptable</th>
<th>Conventional DA approval process

Management practices that meet minimum expectations</th>
</tr>
<tr>
<td>Planning:
• DA approval timeframes exceeded, extensions required for more than 50% of DA’s.
• No electronic lodgement capabilities.
• Conditions on development approvals are unclear and not reasonable and relevant.
• Conditions of development do not match industry expectations or accepted best management practice.
• DA conditions require developer to implement solutions which are more costly than alternatives and do not deliver better outcomes for the community or environment.</td>
<td>Planning:
• DA approval timeframes exceeded, extensions required for more than 50% of DA’s.
• No electronic lodgement capabilities.
• Conditions on development approvals are unclear and not reasonable and relevant.
• Conditions of development do not match industry expectations or accepted best management practice.
• DA conditions require developer to implement solutions which are more costly than alternatives and do not deliver better outcomes for the community or environment.</td>
</tr>
<tr>
<td>Best Practice DA Approval Processing Management

Currently promoted Best Management Practices (BMPs)</td>
<td>Aspirational DA Approval Processing Management

Innovative practices that require further validation</td>
</tr>
<tr>
<td>Planning:
• All Development applications processed within legal timeframes.
• Electronic lodgement of DA’s, electronic lodgement of decisions and conditions
• Good working relationship between Council and development industry, both working together to achieve good outcomes for business and the community.
• Clear, concise, reasonable and relevant and achievable development conditions which reflect best practice.</td>
<td>Planning:
• All Development applications processed within legal timeframes.
• Electronic lodgement of DA’s, electronic lodgement of decisions and conditions.
• Excellent working relationship between Council and development industry, both working together to achieve good outcomes for business and the community.
• Clear, concise, reasonable and relevant and achievable development conditions which reflect best practice, and in cases through mutual agreement may exceed best practice.
• Recognition given for developments which implement infrastructure or have outcomes which exceed best practice.</td>
</tr>
</table>

Energy

Theme Weighting = 1

Dated Urban Energy Planning Management Management practices that are superseded or unacceptable	Conventional Urban Energy Planning Management Management practices that meet minimum expectations
Planning: • No energy efficiency plan for Council offices. • No community energy efficiency plan. • No support for alternative energy schemes from Council or community. • No Council involvement in projects which aim to investigate energy efficiency alternatives.	Planning: • No energy efficiency plan for Council offices. • No community energy efficiency plan. • Minor support and interest for alternative energy schemes from Council or community. • Few Council projects which aim to investigate energy efficiency alternatives.
Best Practice Urban Energy Planning Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban Energy Planning Management** **Innovative practices that require further validation**
Planning: • Energy efficiency plan developed for Council offices. • Community energy efficiency plan developed. • Good support and interest for alternative energy schemes from Council or community. • Council projects which aim to investigate energy efficiency alternatives are incorporated into the Council operational plan. • Solar power used in some community infrastructure. • Landfill gas used to create electricity which is put into local grid (where cost effective). • Develop a policy for 'Green Star' ratings in commercial buildings. • Review Fleet Policy to include hybrid vehicles and encourage the purchase of hybrid replacement vehicles. • Investigate purchase of accredited Green Energy for all or a percentage of Council's energy consumption.	Planning: • Award winning Energy efficiency plan developed for Council offices. • State acknowledged Community energy efficiency plan developed. • Alternative energy schemes embraced by the community and council. • Council projects which aim to investigate energy efficiency alternatives are incorporated into the Council operational plan. • Solar power used in some community infrastructure. • Landfill gas used to create electricity which is put into local grid (where cost effective). • Implement a program of 'Green Star' ratings in commercial buildings. • Adopt green energy as supplier wherever feasible. • Establish Revolving Energy Fund to provide ongoing funds for Council climate change initiatives. • Establish Revolving Energy fund to provide rebates to residents and businesses. • Use of methane production from green waste for co-generation.

Water conservation measures

Theme Weighting = 1

Dated Urban Water Conservation Management **Management practices that are superseded or unacceptable**	**Conventional Urban Water Conservation Management** **Management practices that meet minimum expectations**
• No Council water conservation plan. • Council does not implement water restrictions when supplies are low. • Parkland is irrigated during dry and wet periods. • Public place gardens are irrigated using municipal drinking water. • Public gardens rely heavily on irrigation to keep them growing (poor plant selection). • Municipal water supply is not charged on a user pays principle. • Domestic grey water re-use via garden irrigation is not encouraged. • No Council policy on the use of rainfall tanks. • Groundwater aquifers where water is sourced are not monitored. • No telemetric system used to monitor water supply.	• No Council water conservation plan. • Council implements water restrictions when supplies are less than one year's supply. • Less than 20% of the domestic households use less than 200L/day. • Parkland is irrigated during dry periods. • Public place gardens are irrigated using municipal drinking water. • Public gardens rely heavily on irrigation to keep them growing (poor plant selection). • Municipal water supply is not charged on a user pays principle or cost per Kilolitre. • Domestic grey water re-use via garden irrigation is not encouraged. • No Council policy on the use of rainfall tanks. • Groundwater aquifers are monitored. • Basic telemetric system used to monitor water supply.
Best Practice Urban Water Conservation Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban Water Conservation Management** **Innovative practices that require further validation**
• Council has a water conservation plan. • Council implements water restrictions when supplies are less than two years supply. • More than 50% of the domestic households use less than 200L/day. • Parkland irrigation is on a timer. • Public place gardens are designed so that municipal drinking water is not required for irrigation. This may be a combination of plant species selection, but also alternative sources of water. • Parkland open space irrigation is scheduled to meet the vegetation water use requirements and varies depending on rainfall. • Municipal water supply is charged on a user pays principle, cost per Kilolitre. • Domestic grey water re-use via garden irrigation is encouraged. • Recycled water from sewage treatment plant is used in open spaces for irrigation. • Rain water tanks are encouraged. These tanks are designed to minimise or exclude mosquitoes. • Where municipal water supplies are taken from groundwater sources – these aquifers are renewed to avoid unnecessary drawdown and to prevent saltwater intrusion and damage to the aquifer. • Groundwater aquifers are monitored. • Artificial ground water recharge projects are developed and are generally in place and are working. • Good telemetric system used to monitor water supply.	• Council has a comprehensive water conservation plan which incorporates modelling data, scenarios and promotes the use of innovative water conservation measures.. • Council implements water restrictions when supplies are less than three years supply. • More than 70% of the domestic households use less than 200L/day. • Parkland irrigation is on a timer. • Public place gardens are designed so that municipal drinking water is not required for irrigation. This may be a combination of plant species selection, but also alternative sources of water. • Parkland open space irrigation is scheduled to meet the vegetation water use requirements and varies depending on rainfall. • Municipal water supply is charged on a user pays principle, cost per Kilolitre. • Domestic grey water re-use via garden irrigation is encouraged. • Recycled water from sewage treatment plant is used in open spaces for irrigation. • Recycled water from sewage treatment plant is available for limited usage in residential areas – for example for toilet use and used in open spaces for irrigation. • Rain water tanks are encouraged. These tanks are designed to minimise or exclude mosquitoes. • Where municipal water supplies are taken from groundwater sources – these aquifers are renewed to avoid unnecessary drawdown and to prevent saltwater intrusion and damage to the aquifer. • Groundwater aquifers are monitored. • Artificial ground water recharge projects are developed and are generally in place and are working. • Excellent telemetric systems used to regulate and monitor water usage. • No pigging of water reticulation systems required (no need to l water to maintain pipelines)

Open space management

Theme Weighting = 1

<table>
<tr>
<th>Dated Urban Land Use – Open Space Management

Management practices that are superseded or unacceptable</th>
<th>Conventional Urban Land Use – Open Space Management

Management practices that meet minimum expectations</th>
</tr>
<tr>
<td>• Open space is less than 5% of urban footprint.
• No urban open space plan.
• Low diversity of open space types.
• Open space is not planned.
• Council does not insist on open space contributions.
• Open space is poorly positioned in relation to urban area and consequently is under-utilised.
• All creeks in urban area are degraded and require rehabilitation for habitat purposes and for nutrient removal.
• Open space does not provide a function for stormwater retention or stormwater quality improvement.
• Maintenance is poorly undertaken.
• Coastal reserves are being degraded by human and vehicle usage.</td>
<td>• Open space is less than 5-10% of urban footprint.
• Urban open space planning incorporated into development approvals – no formal plan.
• Low diversity of open space types.
• Open space is poorly planned.
• Council does not insist on open space contributions.
• Open space is poorly positioned in relation to urban area and consequently is under-utilised.
• More than 70-90% of creeks in urban area are degraded and require rehabilitation for habitat purposes and for nutrient removal.
• Open space occurs in floodplain areas but does not perform any functional stormwater management function, and stormwater quality improvement is low.
• Maintenance is adequately undertaken but water usage is not timed or well managed.
• Coastal reserves are in reasonable condition but require formal management guidelines to reduce damage.</td>
</tr>
<tr>
<th>Best Practice Urban Land Use – Open Space Management

Currently promoted Best Management Practices (BMPs)</th>
<th>Aspirational Urban Land Use – Open Space Management

Innovative practices that require further validation</th>
</tr>
<tr>
<td>• Open space is multi-purpose and is widely utilised by a wide range of users.
• Open space activities are planned.
• Open space plan developed and is implemented.
• Open space is planned with defined purposes.
• Future open space areas identified and will be funded through future developments.
• Most open space has facilities which aid in the retention of urban stormwater and its treatment.
• Approximately 30-50% of the degraded urban creeks have been restored (50-70% degraded).
• Strategic timing of grounds maintenance (fertiliser application, mowing, surface stabilisation measures, erosion control) in relation to wet season
• Most Coastal reserves have foreshore management plans which reflect the State Coastal Plan desired goals</td>
<td>• Open space is multi-purpose and is widely utilised by a wide range of users.
• Open space activities are planned.
• Open space plan developed and is implemented.
• Open space is planned with defined purposes.
• Future open space areas identified and will be funded through future developments.
• Most open space has facilities which aid in the retention of urban stormwater and its treatment.
• All degraded creeks have been restored.
• Strategic timing of grounds maintenance (fertiliser application, mowing, surface stabilisation measures, erosion control) in relation to wet season
• All Coastal reserves have foreshore management plans which reflect the State Coastal Plan desired goals.</td>
</tr>
</table>

Development on floodplain areas

Theme Weighting = 2

Dated Urban Land Use – Floodplain Management Management practices that are superseded or unacceptable	Conventional Urban Land Use – Floodplain Management Management practices that meet minimum expectations
Planning: • Subdivisions approved within the 1 in 100 ARI. • Commercial and industry approved in flood plain areas. • Development approved within 1 in 100 ARI storm tide areas. • All road crossings use pipes • All road crossings impede water flow • All urban drains are concrete lined. • Parkland areas have a relatively high use of fertilisers.	**Planning:** • Few subdivisions approved within the 1 in 100 ARI. Conditions placed on developments to reduce risk of possible impacts. • Few commercial and industry approved in flood plain areas. Conditions placed on developments to reduce risk of possible impacts. • Few developments approved within 1 in 100 ARI storm tide areas. Conditions placed on developments to reduce risk of possible impacts. • Between 50-100% of road crossings use pipes • Between 50-100% road crossings impede water flow • Between 50-100% urban drains are concrete lined. • Parkland areas use a low amount of fertiliser.
Best Practice Urban Land Use – Floodplain Management **Currently promoted Best Management Practices (BMPs)**	**Aspirational Urban Land Use – Floodplain Management** **Innovative practices that require further validation**
Planning: • Floodplain development and management plan developed by council to inform planning scheme. • No subdivisions approved within the 1 in 100 ARI. • No commercial and industry approved in flood plain areas. • No development approved within 1 in 100 ARI storm tide areas. Conditions placed on developments to reduce risk of possible impacts. • Between 0 - 50% of road crossings use pipes. Most designed to facilitate fish passage. • Between 0-50% road crossings impede water flow. Most designed to facilitate fish passage. • Between 0-50% urban drains are concrete lined. • Parkland areas do not use fertiliser.	**Planning:** • Floodplain development and management plan developed by council to inform planning scheme. • No subdivisions approved within the 1 in 100 ARI. • No commercial and industry approved in flood plain areas. • No development approved within 1 in 100 ARI storm tide areas. Conditions placed on developments to reduce risk of possible impacts. • No road crossings use pipes, all designed to maintain fish passage. • No road crossings impede water flow all designed to maintain fish passage. • No urban drains are concrete lined unless absolutely necessary. • Parkland areas do not use fertiliser.

Urban centre scoring

Once a grade for each theme has been determined, a corresponding numerical score can be assigned according to

Aspirational = 4 Best Practice = 3 Conventional = 2 Dated = 1

An overall rating for the urban centre can then be calculated using the following equation where S_i and W_i are the n individual theme scores and weightings respectively.

$$Rating(\%) = \frac{\sum_{i=1}^{n} S_i W_i}{\sum_{i=1}^{n} 4W_i} \times 100$$

In some instances, a theme may not be applicable to the urban centre being assessed. For example, the Marine Debris theme would not apply to an inland centre such as Kingaroy. For this reason, the final rating is expressed as a percentage rather than a total for comparative purposes.

Table 33 :Urban scoring explanations

Percentage	Category	Overall rating	Explanation
75-100	A	Very high	**Urban centre is implementation measures which is greatly minimising impacts on nearby waterways**
61-75	B	High	**Urban centre is implementation measures which is minimising impacts on nearby waterways**
47-60	C	Moderate	**Urban centre is implementation measures which is creating a noticeable impact on nearby waterways**
33-49	D	Low	**Urban centre is implementation measures which is creating a moderate impact on nearby waterways**
<33	E	Very low	**Urban centre is potentially polluting nearby waterways and impacts on its physical and chemical composition.**

Appendix 5: Draft Environmental Values and Water Quality Objectives for the Burnett, Baffle, Kolan and Elliott Catchments

Environmental Values and Water Quality Objectives developed under Schedule 1 of the Environmental Protection (Water) Policy 2009 are available for water of the Mary Basin and the Great Sandy Region. Draft EVs and WQOs have been developed for the Burnett, Baffle, Kolan and Elliott catchments. It is anticipated that these draft EV/WQOs will be reviewed in the second half of 2015 towards inclusion of these waters in schedule 1 of the EPP Water in late 2015 or early 2016

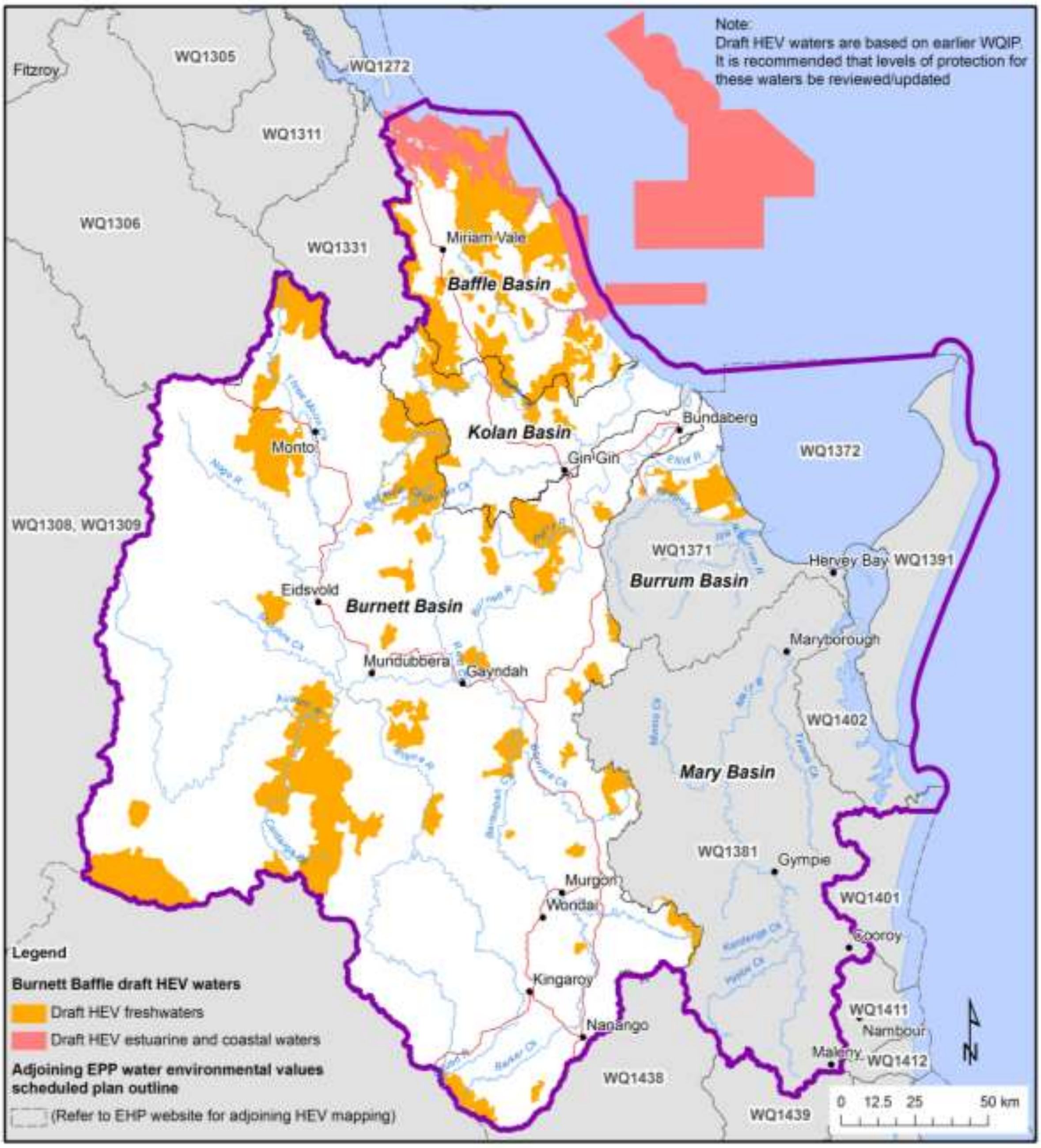

Figure A5.1 : Draft Environmental Values in the Burnett-Mary region and adjacent plan areas scheduled under EPP Water.

Table A5.1.Draft environmental values for waterways in the Baffle, Kolan, Burnett and Elliott catchments.

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
FRESHWATERS													
Baffle Basin													
Littabella Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
Deepwater Ck and tributaries	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓
Baffle Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Rodds Bay / Worthington Ck	✓			✓	✓			✓	✓				
Eurimbula Ck	✓			✓				✓	✓				✓
Kolan catchment													
Gin Gin Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Kolan R above Fred Haigh Dam	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓
Takilberan Ck	✓						✓						✓
Fred Haigh Dam storage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Kolan R between Fred Haigh Dam and Bucca Weir	✓	✓	✓	✓		✓		✓	✓				✓
Bucca Weir pool	✓	✓	✓	✓		✓	✓	✓	✓	✓			
Kolan Barrage Weir Pool	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Freshwater tributaries downstream of Kolan Barrage	✓	✓	✓	✓		✓		✓					
Sandy Ck	✓	✓	✓										
Yandaran Ck (to Rosedale Rd)	✓	✓	✓					✓					✓
Burnett catchment													
Cadarga Ck	✓	✓		✓		✓	✓	✓	✓			✓	✓
Auburn R	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓
Auburn R tributaries	✓												✓
St John Ck	✓			✓		✓			✓			✓	✓
Titi Ck	✓					✓							✓

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Nogo R above Wuruma Dam	✓			✓					✓			✓	✓
Wuruma Dam storage	✓			✓		✓	✓	✓	✓			✓	✓
Nogo R from Wuruma Dam to Burnett R	✓			✓		✓	✓	✓	✓			✓	
Three Moon Ck above Cania Dam storage	✓			✓		✓	✓		✓				✓
Cania Dam storage	✓			✓		✓	✓	✓	✓				
Three Moon Ck from Cania Dam to Burnett R	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Three Moon Ck tributaries below Cania Dam	✓												✓
Bunyip Hole	✓						✓	✓					✓
Fern Pool (or Rock Pool) at Hurdle Gully	✓						✓	✓					
Small weirs on Three Moon Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
Monal Ck above Mungungo Weir	✓			✓					✓			✓	
Mungungo Weir pool	✓	✓	?	✓			✓	✓	✓				

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Monal Ck from Mungungo Weir to Three Moon Ck	✓			✓					✓			✓	
Splinters Ck	✓			✓			✓		✓			✓	
Eastern Ck	✓			✓					✓			✓	
Burnett R above John Goleby Weir	✓			✓		✓	✓	✓	✓			✓	✓
Boyne R above Boondooma Dam storage	✓	✓	?	✓		✓	✓	✓	✓	✓			✓
Stuart R above Gordonbrook Dam storage	✓	✓	✓	✓		✓	✓	✓	✓	✓			
Kingaroy Ck	✓												✓
Gordonbrook Dam storage	✓	✓	✓	✓					✓	✓	✓		
Stuart R from Gordonbrook Dam to Proston Weir	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Proston Weir pool	✓			✓									
Stuart R from Proston Weir to Boondooma Dam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Boondooma Dam storage including pipeline to Tarong	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		
Boyne R from Boondooma Dam to Burnett R	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Barker Ck above Nanango Weir pool	✓	✓	✓	✓		✓	✓	✓	✓	✓			
All waterways within Bunya Mountains	✓								✓				
Nanango Weir pool	✓					✓	✓	✓	✓				
Meandu Ck above Meandu Ck Dam	✓										✓		
Tarong Meandu Ck Dam	✓			✓									
Meandu Ck downstream of dam	✓	✓	✓	✓		✓	✓	✓			?		
Barker Ck from Nanango Weir to Bjelke Petersen Dam	✓	✓	✓	✓		✓	✓	✓	✓	✓			
Bjelke Petersen Dam storage	✓	✓		✓		✓	✓	✓	✓				
Barambah Ck to Francis Weir pool	✓	✓		✓	✓	✓	✓	✓	✓	✓			
Upper Barambah Ck weir pools	✓	✓	✓	✓		✓	✓	✓	✓				

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Barambah Ck weirs to Burnett R & Barker Ck BP Dam to Barambah Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Ban Ban Springs	✓						✓			✓			✓
Barambah Ck weir pools below Bjelke Petersen Dam	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓
Murgon Weir pool	✓									✓	✓		
Cherbourg waterhole	✓	✓						✓		✓			✓
Ficks Crossing waterhole	✓					✓	✓	✓	✓				✓
Boonara Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
John Goleby Weir pool	✓	✓		✓								✓	
Burnett R from John Goleby Weir to Kirar Weir	✓			✓		✓						✓	✓
Kirar (Eidsvold) Weir pool	✓			✓		✓						✓	✓
Burnett R from Kirar Weir to Jones Weir	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓
A Ck and Lochaber Ck	✓												✓
Jones Weir pool	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Burnett R from Jones Weir to Claude Wharton Weir	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓
Aranbanga Ck	✓						✓						✓
Claude Wharton Weir pool	✓	✓	✓	✓		✓	✓	✓	✓	?	✓	✓	✓
Reid Ck	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓
Burnett R from Claude Wharton Weir to Paradise Dam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oaky Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Paradise Dam storage	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
Sunday Ck	✓												✓
Mingo Ck	✓			✓		✓	✓	✓	✓				
Burnett R from Paradise Dam to Ned Churchward (Walla) Weir	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Rocky Ck	✓												✓
Ned Churchward (Walla) Weir pool	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
Perry R and Placer Dam	✓			✓	✓	✓		✓	✓		✓		
Burnett R from Ned Churchward Weir to Ben Anderson Barrage pool	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
Ben Anderson Barrage weir pool (including Bingera)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Tributaries of Ben Anderson Barrage weir pool	✓												✓
Splitters Ck	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓
Bundaberg Ck including Baldwin Swamp	✓			✓			✓	✓	✓				
Coastal cks between Kolan and Elliott Rivers	✓	✓		✓					✓				
Elliot Catchment													
Elliott R	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
ESTUARIES													
Littabella Ck estuary	✓				✓	✓	✓	✓	✓				✓
Rodds Bay / Worthington Ck estuary	✓				✓	✓	✓	✓	✓				✓
Baffle Ck estuary	✓				✓	✓	✓	✓	✓				✓
Deepwater Ck estuary	✓					✓	✓	✓	✓				
Eurimbula Ck estuary	✓					✓	✓	✓	✓				✓
Kolan estuary	✓				✓	✓	✓	✓	✓				✓
Burnett estuary	✓					✓	✓	✓	✓		✓		✓
Elliott estuary	✓				✓	✓	✓	✓	✓				✓

Catchment / Waterway	Aquatic ecosystems	Irrigation	Farm supply	Stock water	Aquaculture	Human consumption of shellfish	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values (non-Indigenous)	Cultural and Spiritual values (Indigenous)
COASTAL/MARINE WATERS													
Coastal waters adjacent to Baffle basin	✓					✓	✓	✓	✓				✓
Coastal waters adjacent to the Kolan/Burnett/Elliott rivers	✓				✓	✓	✓	✓	✓				✓

Table A5.2.Summary of water quality objectives for environmental values of freshwaters for nutrient, chlorophyll a and water clarity parameters(values are in form indicated unless otherwise indicated). Key to guidelines (1) = EPA (2006), (2) = GBRMPA (2006), (3) = ANZECC (2000), (4) = NHMRC (2004), (5) = EPA (2007), (a) =Nitrate – NO_3, (b) = Nitrite – NO_2.

		Ammonia-N	NOx-N	Organic N	Total N	FRP	Total P	Chl-a	TSS	Turbidity	Secchi
Environmental Value	**Water Type**	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	NTU	m
Aquatic Ecosystems HEV	Upland Streams	See WQOs for aquatic ecosystem protection developed from local reference site data (where available)									
Aquatic Ecosystems HEV	Lowland Streams										
Aquatic Ecosystems HEV	Lakes	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Aquatic Ecosystems HEV	Wetlands	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Upland Streams	See WQOs for aquatic ecosystem protection developed from local reference site data (where available)									
Aquatic Ecosystems Slightly to Moderately Disturbed	Lowland Streams										
Aquatic Ecosystems Slightly to Moderately Disturbed	Lakes[(1)]	10	10	330	350	5	10	5.0	nd	1-20	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Wetlands	nd	nd	nd	nd	nd	nd	nd	nd	nd	na
Irrigation[(3)]	Long Term	nd	nd	nd	5,000	nd	50	nd	nd	nd	nd
Irrigation[(3)]	Short Term	nd	nd	nd	25,000 – 125,000	nd	800 – 12,000	nd	nd	nd	nd
Farm Use		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Stock Water[(3)]		nd	400,000[(a)] 30,000[(b)]	nd	nd	nd	nd	nd	nd	nd	nd
Aquaculture	Fresh	1000[1]	1,000-100,000[(a)] 100[(b,1)]	nd	nd	nd	nd	nd	40[(3)]	80[(1)]	nd

		Ammonia-N	NOx-N	Organic N	Total N	FRP	Total P	Chl-a	TSS	Turbidity	Secchi
Human Consumption		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Drinking Water – Raw Water Supply		500 as NH_3 aesthetic[4]	50,000[a] 3,000[b]	nd	nd	nd	nd	nd	25[1]	25[1] or 5 aesthetic[4]	nd
Primary Recreation		10[3]	10,000[a] 1,000[3,b]	nd	nd	nd	nd	nd	nd	nd	>1.6[3]
Secondary Recreation		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Visual Appreciation		nd	nd	nd	nd	nd	nd	nd	nd	<20% redn[3]	<20% redn[3]
Industrial Uses		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cultural and Spiritual Values		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table A5.3. Summary of water quality objectives for environmental values of freshwaters for herbicide, insecticide, fungicide and antifoulant chemicals. Key to guidelines (1) = EPA (2006), (2) = GBRMPA (2006), (3) = ANZECC (2000), (4) = NHMRC (2004), (5) = EPA (2007).

		Ametryn	Atrazine	Diuron	Hexazinone	Simazone	Tebuthiron	2-4-D	Chlorpyrifos	Diazinon	Endosulfan	MEMC	Tributyltin	Irgarol
Environmental Value	**Water Type**	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l	ng/l	µg/l	µg/l	µg/l	µg/l
Aquatic Ecosystems HEV	Upland Streams	nd	0.7[3]	nd	nd	0.2[3]	0.02[3]	140[3]	0.04[3]	0.03[3]	0.03[3]	nd	nd	nd
Aquatic Ecosystems HEV	Lowland Streams	nd	0.7[3]	nd	nd	0.2[3]	0.02[3]	140[3]	0.04[3]	0.03[3]	0.03[3]	nd	nd	nd
Aquatic Ecosystems HEV	Lakes	nd	0.7[3]	nd	nd	0.2[3]	0.02[3]	140[3]	0.04[3]	0.03[3]	0.03[3]	nd	nd	nd
Aquatic Ecosystems HEV	Wetlands	nd	0.7[3]	nd	nd	0.2[3]	0.02[3]	140[3]	0.04[3]	0.03[3]	0.03[3]	nd	nd	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Upland Streams	nd	13[3]	0.2[3]	75[3]	3.2[3]	2.2[3]	280[3]	10[3]	110[3]	0.2[3]	nd	0.002[3]	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Lowland Streams	nd	13[3]	0.2[3]	75[3]	3.2[3]	2.2[3]	280[3]	10[3]	110[3]	0.2[3]	nd	0.002[3]	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Lakes	nd	13[3]	0.2[3]	75[3]	3.2[3]	2.2[3]	280[3]	10[3]	110[3]	0.2[3]	nd	0.002[3]	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Wetlands	nd	13[3]	0.2[3]	75[3]	3.2[3]	2.2[3]	280[3]	10[3]	110[3]	0.2[3]	nd	0.002[3]	nd
Irrigation	Long Term	nd	nd	2[3]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Irrigation	Short Term	nd	nd	2[3]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Farm Use		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Stock Water		5[4a]	0.1[4a]	30[4b]	2[4a]	0.5[4a]	nd	0.1[4a]	10,000[4b]	1,000[4a]	0.5[4a]	nd	nd	nd
Aquaculture	Fresh	nd	0.34[3]	1.5[3]	nd	10.0[3]	nd	4[3]	1[3]	2[3]	0.003[3]	nd	0.026[3]	nd
Human Consumption		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

		Ametryn	Atrazine	Diuron	Hexazinone	Simazone	Tebuthiron	2-4-D	Chlorpyrifos	Diazinon	Endosulfan	MEMC	Tributyltin	Irgarol
Drinking Water – Raw Water Supply		5[4a]	0.1[4a]	30[4b]	2[4a]	0.5[4a]	nd	0.1[4a]	10,000[4b]	1,000[4a]	0.5[4a]	nd	nd	nd
Primary Recreation		nd	nd	40[3]	600[3]	nd	nd	100[3]	2,000[3]	10,000[3]	40[3]	nd	nd	nd
Secondary Recreation		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Visual Appreciation		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Industrial Uses		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cultural and Spiritual Values		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table A5.4. Summary of water quality objectives for environmental values of estuary and marine waters for nutrient, chlorophyll a and water clarity parameters(values are in form indicated unless otherwise indicated). Key to guidelines (1) = EPA (2006), (2) = GBRMPA (2006), (3) = ANZECC (2000), (4) = NHMRC (2004), (5) = EPA (2007), (a) =Nitrate – NO_3, (b) = Nitrite – NO_2.

		Ammonia-N	NOx-N	Organic N	Total N	FRP	Total P	Chl-a	TSS	Turbidity	Secchi
Environmental Value	**Water Type**	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	NTU	m
Aquatic Ecosystems HEV	Upper estuary										
Aquatic Ecosystems HEV	Mid estuary	See WQOs for aquatic ecosystem protection developed from local reference site data (where available)									
Aquatic Ecosystems HEV	Lower estuary / Enclosed coastal										
Aquatic Ecosystems HEV	Open coastal, Marine offshore[2]	nd	nd	nd	nd	nd	nd	coastal 0.5* marine 0.3*	nd	nd	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Upper estuary										
Aquatic Ecosystems Slightly to Moderately Disturbed	Mid estuary										
Aquatic Ecosystems Slightly to Moderately Disturbed	Lower estuary / Enclosed coastal	See WQOs for aquatic ecosystem protection developed from local reference site data (where available)									
Aquatic Ecosystems Slightly to Moderately Disturbed	Open coastal, Marine offshore										
Aquaculture	Marine	100 as NH_3[1]	100,000[a] 100[b,1]	nd	nd	nd	nd	nd	10[3]	na	nd
Primary Recreation	All	10[3]	10,000[a] 1,000[3,b]	nd	nd	nd	nd	nd	nd	nd	>1.6[3]
Secondary Recreation	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

		Ammonia-N	NOx-N	Organic N	Total N	FRP	Total P	Chl-a	TSS	Turbidity	Secchi
Visual Appreciation		nd	nd	nd	nd	nd	nd	nd	nd	<20% redn(3)	<20% redn(3)
Industrial Uses		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cultural and Spiritual Values		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table A5.5. Summary of water quality objectives for environmental values of estuary and marine waters for herbicide, insecticide, fungicide and antifoulant chemicals. Key to guidelines (1) = EPA (2006), (2) = GBRMPA (2006), (3) = ANZECC (2000), (4) = NHMRC (2004), (5) = EPA (2007).

		Ametryn	Atrazine	Diuron	Hexazinone	Simazone	Tebuthiron	2-4-D	Chlorpyrifos	Diazinon	Endosulfan	MEMC	Tributyltin	Irgarol
Environmental Value	**Water Type**	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l	ng/l	ng/l	ng/l	ng/l	ng/l
Aquatic Ecosystems HEV	Upper estuary	nd	nd	nd	nd	nd	nd	nd	0.5[3]	nd	5[3]	nd	0.4[3]	nd
Aquatic Ecosystems HEV	Mid estuary	nd	nd	nd	nd	nd	nd	nd	0.5[3]	nd	5[3]	nd	0.4[3]	nd
Aquatic Ecosystems HEV	Lower estuary / Enclosed coastal	nd	nd	nd	nd	nd	nd	nd	0.5[3]	nd	5[3]	nd	0.4[3]	nd
Aquatic Ecosystems HEV	Open coastal / Marine offshore	nd	nd	nd	nd	nd	nd	nd	0.5[3]	nd	5[3]	nd	0.4[3]	nd
Aquatic Ecosystems Slightly to Moderately Disturbed	Upper estuary	0.2[2]	6.6[2]	1.0[2]	0.9[2]	11[2]	17.5[2]	52.6[2]	20[2]	60[2]	5[2]	2[2]	1[2]	20[2]
Aquatic Ecosystems Slightly to Moderately Disturbed	Mid estuary	0.2[2]	6.6[2]	1.0[2]	0.9[2]	11[2]	17.5[2]	52.6[2]	20[2]	60[2]	5[2]	2[2]	1[2]	20[2]
Aquatic Ecosystems Slightly to Moderately Disturbed	Lower estuary / Enclosed coastal	0.2[2]	6.6[2]	1.0[2]	0.9[2]	11[2]	17.5[2]	52.6[2]	20[2]	60[2]	5[2]	2[2]	1[2]	20[2]
Aquatic Ecosystems Slightly to Moderately Disturbed	Open coastal / Marine offshore	0.2[2]	6.6[2]	1.0[2]	0.9[2]	11[2]	17.5[2]	52.6[2]	20[2]	60[2]	5[2]	2[2]	1[2]	20[2]
Aquaculture	Marine	nd	0.34[3]	1.5[3]	nd	10.0[3]	nd	nd	nd	2[3]	1[3]	nd	10[3]	nd
Primary Recreation	All	nd	nd	40[3]	100[3]	nd	nd	600[3]	2,000[3]	10,000[3]	nd	nd	nd	nd
Secondary Recreation	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Visual Appreciation	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

		Ametryn	Atrazine	Diuron	Hexazinone	Simazone	Tebuthiron	2-4-D	Chlorpyrifos	Diazinon	Endosulfan	MEMC	Tributyltin	Irgarol
Human Consumption	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Industrial Uses	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cultural and Spiritual Values	All	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table A5.6.Draft interim water quality objectives to protect aquatic ecosystem environmental values

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
MARINE AND ESTUARINE WATERS		
Open coastal waters adjacent to the Baffle Creek and Kolan, Burnett and Elliott River catchments [values sourced from Hervey Bay (HB1) WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for HB1 waters are: • turbidity: 0 – 1 – 2 NTU • suspended solids: 2 – 4 – 11 mg/L • chlorophyll a: 0.5 – 0.6 – 0.8 µg/L • total nitrogen: 110 – 113 – 150 µg/L • oxidised N: 2 – 2 – 2 µg/L • ammonia N: 2 – 6 – 9 µg/L: • organic N: 98 – 100 – 140 µg/L • total phosphorus: 6 – 10 – 14 µg/L • filterable reactive phosphorus (FRP): 2 – 2 – 3 µg/L • dissolved oxygen: 90 – 95 – 100% saturation • pH: 8.1 – 8.2 – 8.4 • secchi depth: there is insufficient information available to establish current (20th, 50th, 80th percentile) secchi depth for these waters, and local investigations would be required. Refer to Appendix D in Queensland Water Quality Guidelines for details on how to establish a minimum water quality data set for deriving local 20th, 50th and 80th percentiles (limited existing data suggests 80th percentile > 5.0 m).
Open coastal waters adjacent to the Baffle Creek and Kolan, Burnett and Elliott River catchments [values sourced from Hervey Bay WQOs]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <2 NTU • suspended solids: <11 mg/L • chlorophyll a: <0.8 µg/L • total nitrogen: <150 µg/L • oxidised N: <2 µg/L • ammonia N: <9 µg/L • organic N: <140 µg/L • total phosphorus: <14 µg/L • filterable reactive phosphorus (FRP): <3 µg/L • dissolved oxygen: 90 – 105% saturation • pH: 8.1 – 8.4 • secchi depth: there is insufficient information available to establish current (20th, 50th, 80th percentile) secchi depth for these waters, and local investigations would be required. Refer to Appendix D in Queensland Water Quality Guidelines for details on how to establish a minimum water quality data set for deriving local 20th, 50th and 80th percentiles (limited existing data suggests 80th percentile > 5.0m).

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
Lower Estuary/ Enclosed Coastal (Baffle Creek and Baffle basin estuaries) [using 20th/50th/80th percentiles of EPA data from Baffle Creek reference site (4.1 km from mouth) to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters are: • turbidity: 2 - 3 - 5 NTU • suspended solids: nd • chlorophyll a: 1 - 1 - 2 µg/L • total nitrogen: 110 - 130 - 170 µg/L • oxidised N: 2 - 2 - 2 µg/L • ammonia N: 2 - 2 - 5 µg/L • organic N: 100 - 130 - 160 µg/L • total phosphorus: 6 - 9 - 13 µg/L • filterable reactive phosphorus: 2 - 2 - 2 µg/L • dissolved oxygen: 95 - 100 - 105% saturation • pH: 7.9 - 8.1 - 8.3* • • secchi depth: 1.3 - 2 - 2.5 m
Lower Estuary/ Enclosed Coastal (Elliott) [using 20th/50th/80th percentiles from EPA data from Elliott River reference site (2.0 km from mouth) to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters are: • turbidity: <1 – 1 - 2 NTU • suspended solids: nd • chlorophyll a: 1 – 1 – 1 µg/L • total nitrogen: 110 – 130 - 220 µg/L • oxidised N: 2 – 2 – 2 µg/L • ammonia N: 2 – 2 – 2 µg/L • organic N: 105 – 125 - 216 µg/L • total phosphorus: 5 – 6 - 7 µg/L • filterable reactive phosphorus (FRP): 2 – 2 – 2 µg/L • dissolved oxygen: 95 – 100 - 105% saturation • pH: 8.0 – 8.1 - 8.3* • secchi depth: 2.6 – 4 - 5 m
Lower Estuary/ Enclosed Coastal (Littabella, Deepwater, Kolan and Burnett) [from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <6 NTU • suspended solids: <15 mg/L • chlorophyll a: <2 µg/L • total nitrogen: <200 µg/L • oxidised N: <3 µg/L • ammonia N: <8 µg/L • organic N: <180 µg/L • total phosphorus: <20 µg/L • filterable reactive phosphorus (FRP): <6 µg/L • dissolved oxygen: 90 – 105% saturation • pH: 8.0 - 8.4 • • secchi depth: >1.5 m

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
Mid estuary of Baffle Creek and other Baffle Basin estuaries [using 20th/50th/80th percentiles from EPA data from Baffle Creek reference site (16.0 km from mouth) to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters are: • turbidity: 2 - 4 - 10 NTU • suspended solids: nd • chlorophyll a: 1 - 2 - 4 µg/L • total nitrogen: 150 - 215 - 360 µg/L • oxidised N: 2 - 2 - 6 µg/L • ammonia N: 4 - 6 - 10 µg/L • organic N: 145 - 200 - 340 µg/L • total phosphorus: 12 - 19 - 30 µg/L • filterable reactive phosphorus: 3 - 6 - 10 µg/L • dissolved oxygen: 85 - 90 - 100% saturation • pH: 7.8 – 7.9 - 8.0* • • secchi depth: 1 – 1.5 - 2 m
Mid estuary of the Elliott River and Coonar/Theodolite creeks [using 20th/50th/80th percentiles of EPA data from Elliott River estuary reference site (5.5 km from mouth) to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters are: • turbidity: 2 - 3 - 5 NTU • suspended solids: nd • chlorophyll a: 1 - 1 - 2 µg/L • total nitrogen: 140 - 180 - 230 µg/L • oxidised N: 2 - 2 - 6 µg/L • ammonia N: 2 - 3 - 6 µg/L • organic N: 135 - 165 - 225 µg/L • total phosphorus: 7 - 11 - 14 µg/L • filterable reactive phosphorus: 2 - 2 - 2 µg/L • dissolved oxygen: 85 - 95 - 100% saturation • pH: 7.9 - 8.0 - 8.1* • • secchi depth: 1.6 - 2.3 - 2.8 m
Mid estuary of Kolan and Burnett rivers, Littabella and Deepwater creeks [from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <8 NTU • suspended solids: <20 mg/L • chlorophyll a: <4 µg/L • total nitrogen: <300 µg/L • oxidised N: <10 µg/L • ammonia N: <10 µg/L • organic N: <260 µg/L • total phosphorus: <25 µg/L • filterable reactive phosphorus (FRP): <8 µg/L • dissolved oxygen: 85 – 105% saturation • pH: 7.0 - 8.4 • • secchi depth: >1.0 m

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
Upper estuary of Baffle Creek [using 20th/50th/80th percentiles of EPA data from Baffle Creek upper estuary reference site (35.8 km from mouth) to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters are: • turbidity: 3 - 6 - 11 NTU • suspended solids: nd • chlorophyll a: 2 - 4 - 8 µg/L • total nitrogen: 260 - 360 - 480 µg/L • oxidised N: 2 - 4 - 20 µg/L • ammonia N: 4 - 8 - 18 µg/L • organic N: 250 - 335 - 445 µg/L • total phosphorus: 16 - 35 - 55 µg/L • filterable reactive phosphorus: 2 - 9 - 25 µg/L • dissolved oxygen: 70 - 80 - 100% saturation • pH: 7.4 - 7.7 - 8.0* • secchi depth: 0.2 - 0.3 - 0.5 m
Upper estuary of Burnett River [from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <25 NTU • suspended solids: <25 mg/L • chlorophyll a: <10 µg/L • total nitrogen: <450 µg/L • oxidised N: <15 µg/L • ammonia N: <30 µg/L • organic N: <400 µg/L • total phosphorus: <40 µg/L • filterable reactive phosphorus (FRP): <10 µg/L • dissolved oxygen: 70 – 105% saturation • pH: 7.0 - 8.4 • secchi depth: >0.4 m

* **Note :** following significant freshwater inflows, much lower pH values can be expected

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
FRESHWATERS		
Lowland freshwaters (coastal creeks of the Baffle Basin including Rodds Bay, Eurimbula, Deepwater, Baffle (part) and Littabella (part)) [using 20th/50th/80th percentiles of NRW data from 134001B Baffle Ck at Mimdale reference site to derive WQOs]	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) The 20th, 50th and 80th percentiles of existing water quality for these waters (where data were available) are: • turbidity: 4 - 7 - 9 NTU • suspended solids: 5 - 7 - 11 mg/L • chlorophyll a: nd • total nitrogen: 230 - 355 - 490 µg/L • oxidised N: nd • ammonia N: nd • organic N: nd • total phosphorus: 25 - 40 - 65 µg/L • filterable reactive phosphorus (FRP): nd • dissolved oxygen: nd • pH: 7.3 - 7.7 – 8.0 • secchi depth: nd
Lowland freshwaters (Kolan, Burnett and Elliott catchments)	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) There is insufficient information available to establish water quality objectives for these lowland tributaries, and local investigations would be required.
Lowland freshwaters (Baffle Creek and tributaries and Littabella Creek) [using 20th/80th percentiles of NRW data from 134001B Baffle Ck at Mimdale reference site to derive WQOs]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <9 NTU • suspended solids: <11 mg/L • chlorophyll a: nd • total nitrogen: <490 µg/L • oxidised N: nd • ammonia N: nd • organic N: nd • total phosphorus: <65 µg/L • filterable reactive phosphorus (FRP): nd • dissolved oxygen: nd • pH: 7.3 – 8.0 • secchi depth: nd

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
Lowland freshwaters (Kolan, Burnett and Elliott catchments) [default guidelines for Central east coast lowland freshwaters from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity: <50 NTU • suspended solids: <10 mg/L • chlorophyll a: <5 µg/L • total nitrogen: <500 µg/L • oxidised N: <60 µg/L • ammonia N: <20 µg/L • organic N: <420 µg/L • total phosphorus: <50 µg/L • filterable reactive phosphorus (FRP): <20 µg/L • dissolved oxygen: 85 – 110% saturation • pH: 6.5 – 8.0 • secchi depth: nd
Upland freshwaters (Baffle, Kolan and Burnett catchments)	Aquatic ecosystem – high ecological value (level 1)	Maintain existing water quality (20th, 50th and 80th percentiles). (Refer to Appendix D in Queensland Water Quality Guidelines for details.) There is insufficient information available to establish water quality objectives for these upland waters, and local investigations would be required.
Upland freshwaters (Baffle, Kolan and Burnett catchments) [default guidelines for Central east coast upland freshwaters from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	There is insufficient information available to establish water quality objectives for these upland waters, and local investigations would be required. • turbidity: <25 NTU • suspended solids: <6 mg/L • chlorophyll a: <2 µg/L • total nitrogen: <250 µg/L • oxidised N: <15 µg/L • ammonia N: <10 µg/L • organic N: <225 µg/L • total phosphorus: <30 µg/L • filterable reactive phosphorus (FRP): <15 µg/L • dissolved oxygen: 90 – 110% saturation • pH: 6.5 – 7.5 • secchi depth: nd

Water area / type	Level of protection	Water quality objectives to protect aquatic ecosystem EV
Reservoirs in the Burnett and Kolan River catchments [default guidelines for freshwater lakes/reservoirs from QWQG]	Aquatic ecosystem – slightly to moderately disturbed (level 2)	• turbidity range: 1-20 NTU • suspended solids: nd • chlorophyll a: <5 µg/L • total nitrogen: <350 µg/L • oxidised N: <10 µg/L • ammonia N: <10 µg/L • organic N: <330 µg/L • total phosphorus: <10 µg/L • filterable reactive phosphorus (FRP): <5 µg/L • dissolved oxygen: 90% – 110% saturation • pH: 6.5 – 8.0 • secchi depth: nd
Wetlands in the Baffle Creek and Kolan, Burnett and Elliott River catchments	Aquatic ecosystem – slightly to moderately disturbed (level 2)	There is insufficient information available to establish water quality objectives for wetlands, and local investigations would be required.

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand. Environment Australia, Canberra.

EPA (2006). Queensland Water Quality Guidelines. Queensland Environmental Protection Agency, Brisbane. 121 pp.

EPA (2007). Burrum, Gregory, Isis, Cherwell and Elliott Rivers Environmental Values and Water Quality Objectives Basin No. 137 (part) Including all Hervey Bay coastal rivers and creeks. Environmental Protection Agency, Brisbane.

GBRMPA (2007). Interim marine water quality guidelines for the Great Barrier Reef Marine Park (Draft).

Great Barrier Reef Marine Park Authority, Townsville. 87 pp.

NHMRC (2004). Australian Drinking Water Guidelines 6. National Health and Medical Research Council, and Natural Resource Management Ministerial Council. Australian Government, Canberra. 615 pp.

NHMRC (2006). Guidelines for Managing Risks in Recreational Water. National Health and Medical

Research Council. Australian Government, Canberra. 219 pp. {Note: these guidelines suggest the use of ADWG as a guide to water quality for recreational use)

1=EPA (2006), 2=GBRMPA (2007), 3=ANZECC (2000), 4=NHMRC (2004), 5=EPA (2007).

Glossary of Terms and Abbreviations

Term	Definition
ABS	Australian bureau of statistics
AEB	The annuity which results in the same value as the net present value of an investment.
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.
APSIM	The Agricultural Production Systems sIMulator (APSIM) is internationally recognised as a highly advanced simulator of agricultural systems.
BCR	Benefit cost ratio
BMP	Best management practice
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
DON	Dissolved organic nitrogen
DOP	Dissolved organic 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
Environmental values	Environmental values 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
Great Barrier Reef catchment	The 35 river basins in Queensland which drain into the Great Barrier Reef.
INFFER	Investment Frameworks for Environmental Resources; www.inffer.com.au
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.
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.
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

Term	Definition
	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
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.
River basin	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).*
TSS	Total suspended solids
WQIP	Water quality improvement plan
WQO	Water quality objectives