Department of Environment and Heritage Protection

REEF WATER QUALITY

Reef Water Quality Research, Development and Innovation Strategy

2014-15–2018-19

Queensland Government

Prepared by: Reef Water Quality Unit, Department of Environment and Heritage Protection

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#30749

Foreword

The Great Barrier Reef—one of the world's most beautiful and biologically diverse natural wonders—makes an enormous contribution to the economic and social wellbeing of all Queenslanders.

The Queensland Government is committed to ensuring that this precious icon is conserved to international standards for future generations, while still contributing to the state's prosperity.

The quality of water entering the Great Barrier Reef from the adjacent catchments remains a major management issue for protecting the Great Barrier Reef World Heritage Area, particularly from the excess nutrients, pesticides and sediment.

In response to the ongoing water quality impacts, the Queensland Government has set ambitious targets to reduce nitrogen and suspended sediment run-off from key reef catchments, by up to 80 per cent and 50 per cent respectively, by 2025.

To achieve these targets and to grapple with this persistent problem, we will help producers adopt practices that minimise this pollution runoff. For this to happen, science and research needs to continuously evolve to inform the development and adoption of practices beneficial to the reef.

This Reef Water Quality Research, Development and Innovation Strategy responds to these needs, and will generate information vital to help key producers and managers make essential practice improvement decisions. The strategy focuses on the key reef catchments (Wet Tropics, Burdekin, Fitzroy and Mackay-Whitsunday) and priority pollutants identified within the Reef Water Quality Protection Plan (Reef Plan).

Outcomes from the science-based program will also inform future government direction and management interventions across the whole of reef catchments. Improved evidence from projects completed in the previous science program has already identified which sub-catchments and issues should be addressed within the limited resources available across Reef Plan partners. This strategy will continue to support investment in innovative policy responses.

The science-based program has been developed to guide the Queensland Government's investment in research and to seek partnerships to foster management practice improvement that delivers profit, productivity and environmental benefits. The framework and research priorities underpinning this program were reviewed with input from industry, scientific experts, Natural Resource Management (NRM) groups and other stakeholders.

This science strategy will help achieve the Queensland Government's targets by supporting primary producers and extension providers and, in turn, help give the reef the best prospect for long-term survival.

Dr Steven Miles
Minister for Environment and Heritage Protection
Minister for National Parks and the Great Barrier Reef

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Introduction

The Australian and Queensland governments have worked collaboratively to develop a Long-Term Sustainability Plan for the Great Barrier Reef World Heritage Area that guides the protection and management of this iconic world heritage area through to 2050.

The Reef Water Quality Protection Plan (Reef Plan) that sits under the Long Term Sustainability Plan is a collaborative program of coordinated projects and partnerships designed to improve the quality of water in the Great Barrier Reef through improved broad-scale land management in reef catchments. To achieve Reef Plan targets and outcomes, issues and risks need to be clearly assessed and defined at the appropriate scales, and actions prioritised using best available information.

Priorities for research, development and innovation need to be determined over the short and long terms. The updated Reef Plan Research, Development and Innovation (RD&I) Strategy sets out priority research gaps.

The Reef Water Quality RD&I Strategy fits within the Reef Plan RD&I, describing and prioritising the Department of Environment and Heritage Protection's (EHP) investment in reef water quality, management practice, research and science delivery.

Science delivery will be linked to Actions under Reef Plan to ensure that information is passed to users in the best way to inform decisions.

Between 2009 and 2014, EHP's Reef Water Quality (RWQ) science program provided much-needed products to extension providers and landholders. This included an understanding of reef catchments, the sources of the greatest pollutants (nutrients, pesticides and sediment) affecting the reef, and processes within these catchments that generate these pollutants, such as subsurface erosion from gullies. Other product outputs included vital scientific evidence about priority management practices and tools to help landholders make decisions. This science also informed Reef Plan 2013, the associated Scientific Consensus Statement 2013, and the updated Reef Plan RD&I Strategy.

The RWQ science program also aimed to enhance the information and evidence that helps producers decide how to improve practices on their properties. Hence, this information was, and will continue to be, translated into extension tools and knowledge.

Scope

The RWQ science program will build upon previous research and also support the Queensland Government's policy response to improving the quality of water entering the Great Barrier Reef. This science program is a collaborative venture, aiming to continue and extend partnerships, encourage co-investment, enhance scientific outcomes, and distribute new knowledge to effect on-ground changes that will improve the reef's resilience.

The RWQ RD&I Strategy focuses on:

- priority pollutants (nitrogen, pesticides and sediment) across reef catchments
- the effectiveness of management practices, decision support systems for producers and prioritising investment and policy response
- agricultural production systems of grazing, sugarcane growing and banana production. However, the strategy can be reviewed and expanded as emerging issues arise; for example, increases in other cropping systems within reef catchments such as rice.

Projects responding to this strategy will be largely limited to a period of up to three years, allowing results to inform Reef Plan's mid-term review. This strategy and its projects will then respond to the findings of the review.

Implementing this strategy will depend upon available funds. While it has been developed with known existing and future budget capacity, the extent of future funding may require adjustments to be made to the RWQ RD&I Strategy and opportunities for collaboration with partners will be necessary. The strategy continues to invest in cane and Burdekin grazing industries, with the addition of banana growing in the Wet Tropics and erosion management on Fitzroy grazing lands, which the consensus statement recognised as an industry of significance. Some investment will also support emerging issues and synthesis of information under Reef Plan.

Development of the RWQ RD&I Strategy

A review of the RWQ 2011–14 science program and program logic simplified the portfolio framework and overarching research questions to ensure alignment with the Reef Plan RD&I Strategy. It also ensured that current knowledge is reflected, ensuring that limited funds are channelled into priority areas in keeping with the RWQ Program's remit.

This involved:

- an in-house review of the Reef Plan RD&I Strategy priorities to:
  - check against the 2011–14 RWQ science program, assessing common research gaps and emerging needs
  - consider remaining priorities against RWQ program commitments
  - consider the outcomes of the 2011–2014 RWQ science program
- external review of draft RWQ RD&I Strategy (October 2014) to:
  - confirm themes and priorities
  - review identified research gaps and needs against desired RWQ Program outcomes for the cane, grazing and banana industries in identified catchments
  - confirm alignment or risks of duplication and potential collaborations with other research and reef-related programs
  - identify if emerging information and synthesis reports would change the overall priorities.

The RWQ RD&I Strategy and priorities will evolve over time in response to outcomes from other research programs, future water quality improvement plans (WQIPS) and emerging issues.

Alignment with the Reef Plan RD&I Strategy

Each of the research questions addressed by RWQ science program aligns with the updated Reef Plan RD&I Strategy. This strategy was developed after a robust process of consultation, review and redefinition of program logic and underpinning research questions and priorities.

Alignment will ensure integration of research programs undertaken by Reef Plan partners. It also gives EHP confidence that the RWQ RD&I Strategy aligns with the interests and priorities identified by industry and other research stakeholders. Strong partnerships and collaborative research activities will build on the synthesis of the most recent information, dissemination of new knowledge to end-users, and co-investment of limited research funds. Priority reef catchments, and the risk posed by priority pollutants identified under the 2013 Scientific Consensus statement, are shown in Table 1a and 1b.

Table 1a: Priorities for pollutants and catchments

Catchment /region	Relative risk	Priority pollutants for management		
		Nitrogen	Pesticides	Sediment
Cape York	LOW			
Wet Tropics	VERY HIGH	VERY HIGH	HIGH	
Burdekin	HIGH	VERY HIGH	VERY HIGH	VERY HIGH
Mackay Whitsundays	MODERATE	HIGH	VERY HIGH	
Fitzroy	HIGH		HIGH	VERY HIGH
Burnett Mary	UNCERTAIN			HIGH

(Brodie, J. et al. 2013. Assessment of the risk of pollutants to ecosystems of the GBR including differential risk between sediments, nutrients and pesticides and between land uses, industries and catchments. Project funded by Queensland Government Department of Environment and Heritage Protection as part of the Reef Plan Scientific Consensus Statement 2013).

Updates to regional WQIPs by regional NRM bodies, based on best-available information, will help further define local and regional priorities for management practice change and interventions, focusing attention by industry and by geographic sub-catchments and local areas. This will then inform local extension and information requirements to meet targets under Reef Plan.

Table 1b: Priorities for pollutants and catchments

Relative priority	Management priorities			
	Region	Pollutant management	Key land uses	Comments
1	Wet Tropics	Fertiliser nitrogen reduction	Sugarcane, Bananas	Note that these actions should not be prioritised at the exclusion of other practices that are already in place to manage losses of other pollutants in the regions
	Burdekin	Erosion management in Burdekin	Grazing	
	Fitzroy	Erosion management in Fitzroy	Grazing, Cropping	
2	Burdekin	Pesticide reduction in (lower) Burdekin and Haughton	Sugarcane	
	Mackay Whitsunday	Pesticide reduction in all catchments	Sugarcane	
	Burdekin	Fertiliser nitrogen reduction in (lower) Burdekin and Haughton	Sugarcane	
3	Mackay Whitsunday	Fertiliser nitrogen reduction	Sugarcane	
	Burnett Mary	Erosion management in all catchments	Grazing	
	Wet Tropics	Pesticide reduction in all catchments	Sugarcane	
	Fitzroy	Pesticide reduction in all catchments	Grazing, cropping	
4	Burnett Mary	Further information is required to inform the assessment, including data on the full extent and condition of corals and seagrass (which are outside the Great Barrier Reef World Heritage Area) in the region	Habitat mapping, ecological value assessment and monitoring of ecosystem condition is required	
5	Cape York	Further information is required to understand local influences	As a relatively low impacted area, management efforts should aim to maintain the current values of the region	

(Scientific Consensus Statement Update Table 10: Summary of management priorities for reducing the relative risk of degraded water quality to the Great Barrier Reef. Source: Brodie et al., (2013a))

Objectives

The key objectives of the RWQ science program are to:

- enhance evidence about the effectiveness of property management systems and practices that can improve the quality of water entering the reef while maintaining or enhancing production and profitability
- prioritise investment and policy responses to deliver the most effective on-ground change, where required
- develop and communicate clearer guidance and practical tools to help agricultural producers adopt management practices that improve productivity, profitability and water quality outcomes.

Outcomes

The RWQ science program will:

- seek to increase certainty and confidence about the most cost-effective ways to manage priority reef pollutants in priority sub-catchments
- deliver and extend producers learnings, tools and advice from investment during 2009–14, where these can directly improve management practice on-farm
- expand the legacy of successful products and information to other reef catchments where there is an expectation of, and desire for, products to encourage management practice improvement adoption, as well as focusing extension programs in priority areas
- establish action research and demonstration projects in local communities to support awareness of water quality impacts and champion management practice change in priority areas and priority agricultural activities
- enhance delivery of Reef Plan, and meet the Queensland Government's targets, by investing in improved evidence to prioritise actions and management interventions
- provide a foundation for collaboration and co-investment in research programs and translating research into extension tools and advice.

Structure of RWQ RD&I Strategy

Figure 1 shows that the RD&I research gaps and questions are grouped under two focal research areas and four themes. The two focal research areas, described in box 1 below are:

A. Farm management systems

B. Prioritising investment and responses

These focal research areas reflect the direction of the previous science program logic and summarise the original 101 research questions, posed in 2009, into five overarching research questions, also described inbox 1.

The critical land uses—each with priority pollutants for management—are sugarcane, grazing and bananas. The four key themes within these land uses are:

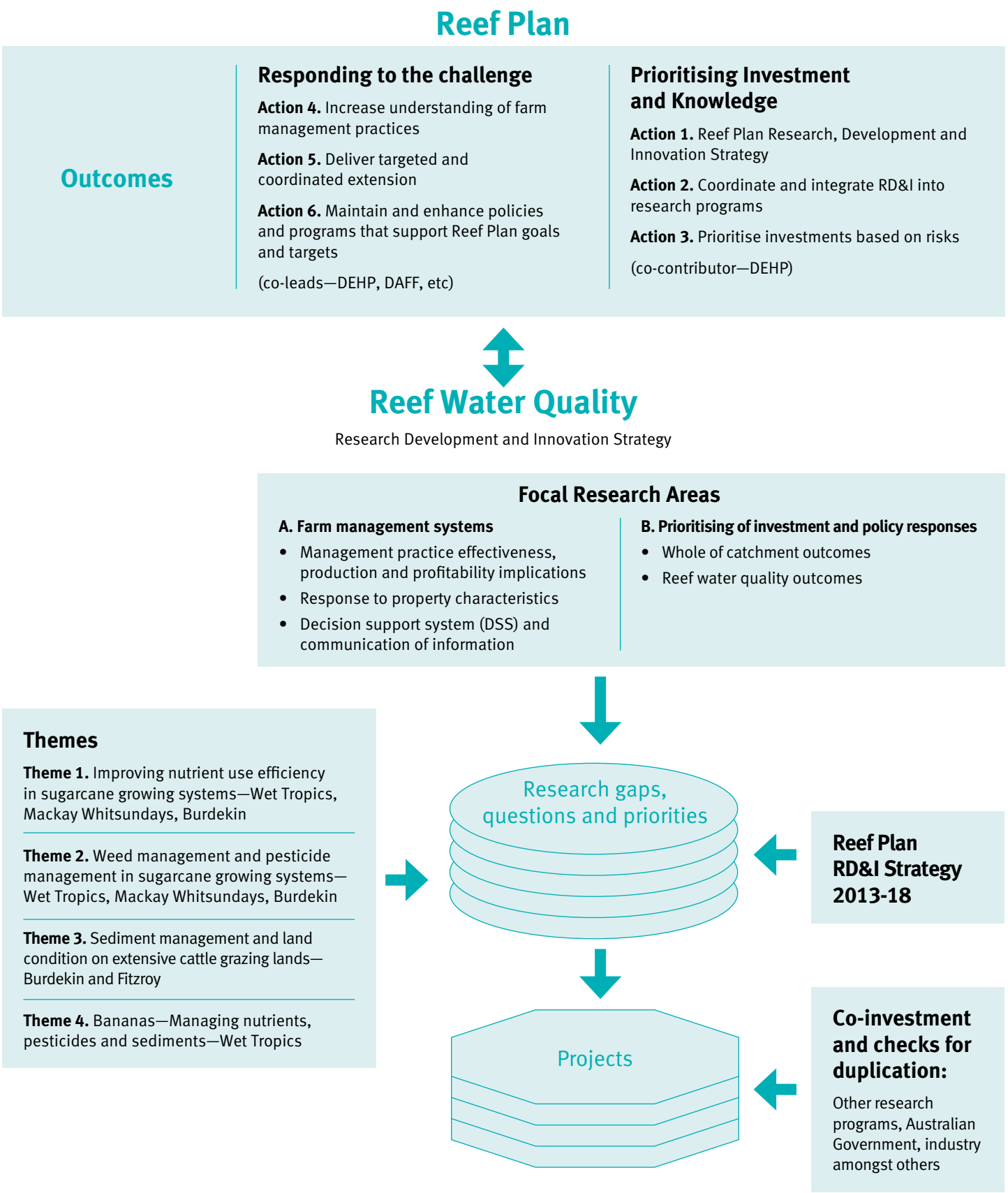
- Theme 1 Improving nutrient use efficiency in sugarcane growing systems
- Theme 2 Managing weeds and pesticides in sugarcane growing systems
- Theme 3 Managing sediment and land condition on extensive cattle grazing lands
- Theme 4 Managing nutrients, pesticides and sediments in banana growing systems

A summary of the major research needs/priorities across the themes and focal research areas is provided in Box 2 on page 11. Research gaps and responding projects under these themes mainly relate to Focal Research Area A—Farm management systems—and the need to effect change on properties.

The program under Focal Research Area B–Prioritising investment and policy responses–will continue to evolve in line with government directions, and the need for innovative policy responses. This will be informed by emerging management interventions to meet the Queensland Government targets for reef water quality outcomes.

Box 2 also recognises the need for practical investment and action (i.e. co-investment in monitoring stations, developing synthesis reports) to build knowledge among managers and investors about where to direct on-ground action and policy responses. Information gained will enable relative risks of pollutants to the reef to be assessed and priority areas for managing pollutants' sources to be identified, as well as supporting future updates of Reef Plan and the Scientific Consensus Statement, as required.

Figure 1: RD&I framework for RWQ science program



Box 1: Focal research areas and questions

A. Farm management systems

- Management practice effectiveness, production and profitability implications
- Response to property characteristics
- Decision-support systems (DSS) and communicating information—includes sharing technical methodologies through extension networks

Work in this area will seek to effect changes in property/production system management by investigating the effectiveness of improved practices and better communicating findings to land managers through decision tools and information services (this includes demonstrations of practices in the paddock, or industry best management programs). Potentially, developing and testing technical methodologies that improve understanding of property characteristics could be undertaken, such as ground cover mapping.

B. Prioritising investment and policy responses

- Whole of catchment outcomes
- Reef water quality outcomes

Work in this area will build knowledge among managers and investors about where to direct on-ground action and policy responses. Information gained will enable relative risks of pollutants to the reef to be assessed and priority areas for managing pollutants' sources to be identified.

Overarching research questions under Focal research areas A and B are:

A1. What are the farm/grazing management systems that are most cost-effective to reduce diffuse pollutant loads while improving land condition and production outcomes? What are the barriers to uptake of these systems and how can they be overcome?

A2. Which landscape characteristics need to be considered when maximising production efficiency and minimising sediment, nutrient and pesticide losses (for example, managing soils vulnerable to erosion in agricultural lands and for drought preparedness)?

A3. Which decision-support tools or information products could be enhanced to improve management practice decision-making?

B1. Which pollutants and pollutant-generating practices and processes should be targeted? Which sub-catchment areas are contributing the most significant loads?

B2. Which management systems and policy changes relating to broad scale agriculture (and how it is changing) could enhance the quality of water entering the reef and improve its long-term health and resilience?

Box 2: Summary of priorities under Reef Water Quality science program

Where and why do we invest in Great Barrier Reef catchments?

- Synthesise detailed knowledge since 2013 Scientific Consensus Statement: sediment management in grazing lands Burdekin and Fitzroy, nutrient use efficiency in sugar cane (Australian Government led), and pesticides in reef catchments
- Extend information to producers to direct practice change (e.g. decision support tools, demonstration farms)
- Identify priority pollutant management activities and areas for investment, policy response and management intervention

Audience: policy, industry, extension, researchers

Theme 1. Sugar Cane—nutrient use efficiency

Wet Tropics, Lower Burdekin

- Nutrient use efficiency (e.g. Wet Tropics, Burdekin cane trials)
- Optimal management practice options and economic implications and local grower response through action research projects

Audience: growers, extension networks, policy

Theme 2. Sugar Cane—weed and pesticide management systems

Wet Tropics, Burdekin, Mackay Whitsunday

- Optimal weed management and pesticide strategies, economic implications and local grower response through action research projects
- Optimal management practice options and economic implications
- Understand use and potential impact from alternative pesticides on reef resilience and need for change in best management standards

Audience: growers, extension networks, policy

Theme 3. Cattle grazing—sediment management and land condition

Burdekin and Fitzroy

- Expand mapping of vulnerable soils and gullies into the Fitzroy catchment
- Enhance extension tools and information of land condition for landholders (e.g. groundcover) and undertake ground-truthing within the Fitzroy catchment
- Confirm best investment in land condition enhancement versus gully prevention and remediation, with clarification of impact from nutrients attached to sediment
- Transfer of emerging landscape knowledge to increase accuracy of models under Paddock to Reef Monitoring and Modelling Program to assess volume and spatial contribution of sediment sources

Audience: graziers, extension networks, policy, researcher

Theme 4. Banana—managing nutrients, pesticides and sediments

Wet Tropics

- Nutrient use efficiency, optimal management practice options and economic implications
- Optimal weed management practices and pesticide strategies, economic implications
- Optimal sediment management systems options including economic implications
- Economic implications of the adoption of best practices of Banana BMP

Audience: industry, external networks, policy

Farm Management Systems

Prioritisation

Themes (by production systems)

The following sections describe the key issues and emerging trends, and summarise the priority research gaps by theme. The high-medium priority research gaps for each theme aligned with the focal areas are described in Figure 2–5 and detailed research questions are listed in Appendix 1.

In the research priority descriptions that follow, research gaps have been labelled using references to the theme and focal research area to which they relate.

Theme labels are cane (C), grazing (G) and bananas (B). Focal research area labels are management practice effectiveness (MP), response to property characteristics (PC), decision support systems (DS) and prioritisation of investment and responses (Pr). Thus, a research gap related to cane management practice effectiveness is labelled CMP, or a grazing property characteristics gap is tagged as GPC.

More detail is provided in Appendix 1, which provides the longer list of research questions against each research gap, and links to the Reef Plan RD&I strategy.

Theme 1. Improving nutrient use efficiency in sugarcane growing systems —Wet Tropics, Burdekin, Mackay Whitsundays

Nutrients of concern to reef health are nitrogen and phosphorus as they are both bio-available in aquatic environments, driving the proliferation of algal blooms in freshwater and marine ecosystems. The 2013 Scientific Consensus Statement confirmed that nitrogen run-off is one of the greatest water quality risks to reef health as it is associated with outbreak cycles of coral-eating crown-of-thorns starfish, hence the higher management priority. The relative risk of phosphorus losses, particulate forms of nutrients and dissolved organic nitrogen (e.g. urea), especially from areas of continued high application rates, requires further investigation. Runoff of dissolved inorganic nitrogen (DIN) has been related to nitrogen fertiliser applications in sugarcane production and the associated high nitrogen surpluses (the difference between nitrogen input and nitrogen readily taken up by the crop) with this practice.

Reef Plan 2013 acknowledges that, based on scenario modelling, 100 per cent adoption of the current industry best practice system for nutrient management, Six Easy Steps (6ES) using a district yield potential (DYP), will only deliver a 15–30 per cent reduction in DIN transported to the reef from catchment agriculture. The current Reef Plan target is to achieve a 50 per cent reduction in DIN by 2018. The sugarcane industry has committed to improving the current industry best practice for nutrient management (6ES using DYP) by 2017 following the results of a cooperative research program culminating in 2016. The EHP RWQ science program, along with the work of Sugar Research Australia (SRA), the Australian Government, and other relevant research partners, will contribute to this overall body of research.

The Australian Government Reef Rescue Programme has provided funding to SRA to synthesise current information about improving nutrient use efficiency in sugarcane. Relevant research partners—SRA, Australian Government, and the RWQ program, amongst others—will consider the draft findings as part of developing forward research programs. The research program and partnership will be formalised following the release of this draft report in December 2014.

The effectiveness of nutrient management strategies is a key element of this theme. While sediment management plays a role in managing the loss pathways of bonded nutrients and pesticides, efforts to manage nutrient sources (i.e. fertiliser application) is of greater importance. Nutrient use efficiency relates to understanding the best nutrient rates and application regimes to be applied, given site-specific soil characteristics. Decisions within farm management systems also include placement, application, and timing method through to irrigation and weather. Irrigation strategies and managing water flow in cane lands could be considered to complement other nutrient, pesticide and sediment management strategies.

There is need for confidence-building to support on-farm practice change, such as through decision-support systems, demonstration projects and engaging with the cane-growing community through action research.

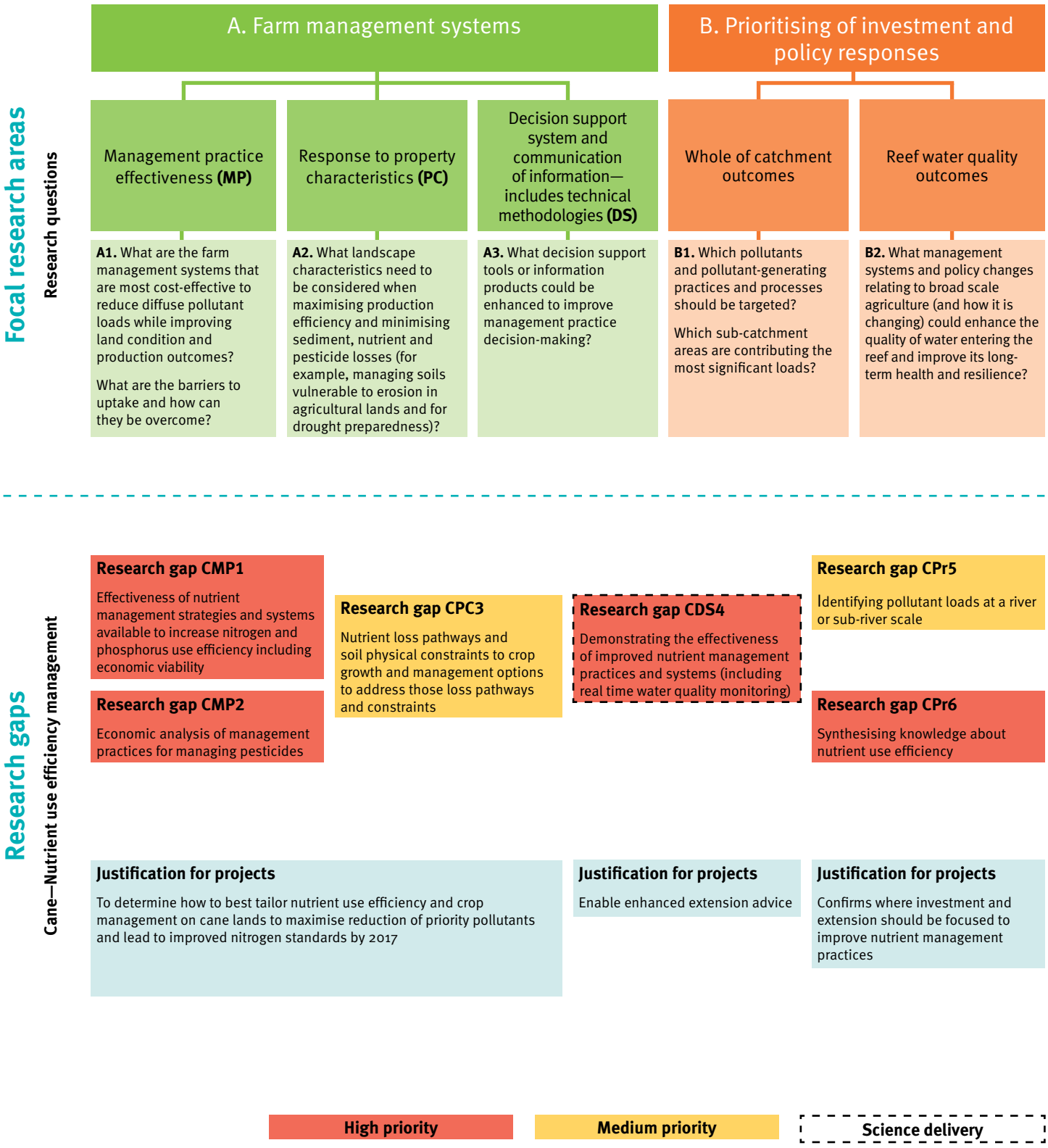
Table 2 lists the priority research gaps and priorities for cane nutrient management, and Figure 2 presents these gaps and priorities against the focal research areas of the RWQ RD&I Strategy.

Table 2: Priority research gaps and priorities for cane nutrient use efficiency management

Research gap	Priority
CMP1 Effectiveness of nutrient management strategies and systems available to increase nitrogen (N) and phosphorus (P) use efficiency including economic viability	High
CMP2 Economic analysis of management practices for managing nutrients	High
CPC3 Nutrient loss pathways and soil physical constraints to crop growth and management options to address those loss pathways and constraints	Medium
CDS4 Demonstrating the effectiveness of improved nutrient management practices and systems (including real time water quality monitoring)	High Science delivery*
CPr5 Identifying pollutant loads at a river or sub-river scale	Medium
CPr6 Synthesising knowledge about nutrient use efficiency	High

*Science delivery indicates where there is a key gap in how the information is translated to the producers to achieve on-ground management practice change.

Figure 2: Reef Water Quality Science Program—cane—nutrient use efficiency research gaps and justification



Theme 2. Weed management and pesticide management in sugarcane growing systems—Wet Tropics, Mackay Whitsundays, Burdekin.

Whole-of-farm pesticide and weed management (not only priority pesticides) is critical to limiting the impacts of pesticides on reef water quality and supporting ecosystems. Pesticides pose a risk to freshwater, inshore and coastal ecosystems, as their presence in waterways and in the reef lagoon reduces the resilience of aquatic ecosystems. Diffuse source pollution from agriculture is the largest contributor to pesticide loads in the reef lagoon, with sugar cane cultivation and beef cattle grazing comprising the majority of land uses in reef catchments.

Chemical use in agriculture is regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the Queensland Chemical Usage (Agricultural and Veterinary) Control Regulation 1999. Regulation covers chemical application, such as adherence to label instructions, consideration of weather and site characteristics.

Current information about impacts and management of pesticide across industries (including sugar cane) will be collated in early 2015. Reducing pesticide loads transported to the reef is a detailed issue due to the complexity of defining pesticide movement pathways through the environment from agricultural land to the Great Barrier Reef. At present, there are varying levels of research attention given to pesticide use rates, application methods, off-site transport, impacts on aquatic ecosystems and water quality guidelines describing tolerable pesticide levels within environments. The outcomes of the project will provide recommendations for government and industry management, and investment in identified priority areas.

Alternative pesticides have been detected in reef catchments, at sometimes high concentrations, and can present the same or higher risk to the environment as the current priority regulated pesticides. The toxicity of all pesticides in the reef ecosystem, the toxicity of combinations of pesticides, and the synergistic impacts of pesticides and other pollutants like sediment and nutrients, remains a gap in existing knowledge. Improving our understanding of this issue may enhance policy responses and extension activities. The synthesis project should also prioritise research needs in this area for relevant research programs such as National Environmental Science Program (NESP).

It is generally accepted that information and advice on effective weed management strategies and appropriate use of chemicals are available to growers. However, there are gaps in understanding the benefits of integrated weed management and understanding the impacts and circumstances of pesticide movement on and off-farm. Targeted, resourced and good quality extension efforts will help implement effective weed management strategies.

Constructed wetlands and tail-water pits can be useful to capture pesticides coming off paddocks in the first flush within the Burdekin. Recent science has identified that these systems are less effective in high rainfall-driven systems such as the Wet Tropics. Work funded by the Australian Government is further assessing the effectiveness of these systems in the Burdekin.

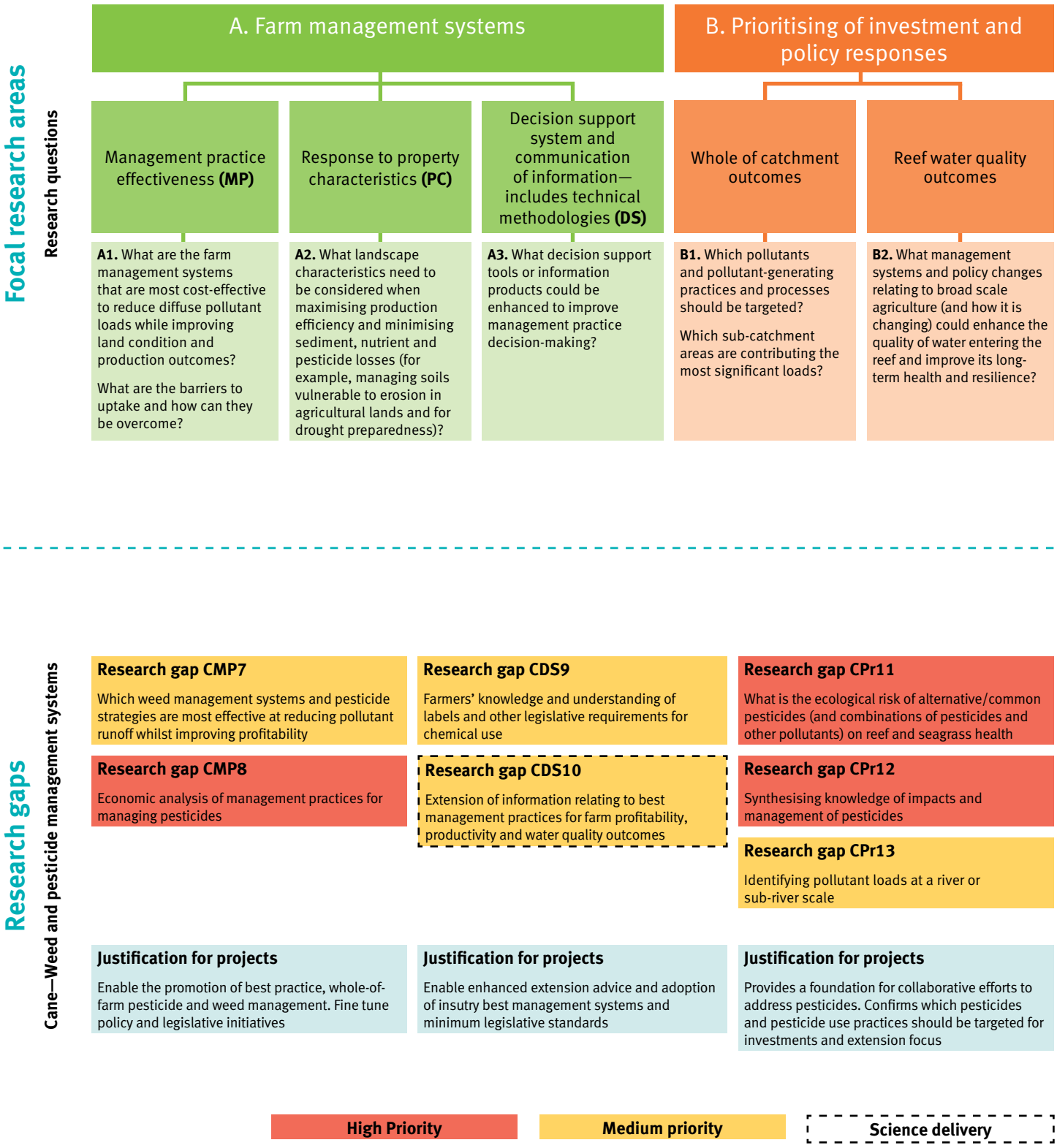
Table 3 lists the priority research gaps and priorities for cane weed management, and Figure 3 presents these gaps and priorities against the focal research areas of the RWQ RD&I Strategy.

Table 3: Research gaps and priorities for cane — weed and pesticide management systems

Research gap	Priority
CMP7 Which weed management systems and pesticide strategies are most effective at reducing pollutant runoff whilst improving profitability?	Medium
CMP8 Economic analysis of management practices for managing pesticides	High
CDS9 Farmers' knowledge and understanding of labels and other legislative requirements for chemical use	Medium
CDS10 Extension of information relating to best management practices for farm profitability, productivity and water quality outcomes	Medium Science delivery*
CPr11 What is the ecological risk of alternative/common pesticides (and combinations of pesticides and other pollutants) on reef and seagrass health?	High/ Medium
CPr12 Synthesising knowledge of impacts and management of pesticides	High
CPr13 Identifying pollutant loads at a river or sub-river scale, in priority areas from cane and other commodities	Medium

*Science delivery indicates where there is a key gap in how the information is translated to the producers leading to on-ground management practice change.

Figure 3: Reef Water Quality Science Program—cane—weed and pesticide management research gaps and justification



Theme 3. Sediment management and land condition on extensive cattle grazing lands—Burdekin and Fitzroy

Sediment loads entering the Great Barrier Reef may impact on its long-term health due to:

a) the physical impacts of smothering and blocking of light from sediment loads carried by flood plumes and re-suspension events on aquatic ecosystems such as seagrass and inshore coral reefs;

b) the contribution of particulate nutrients (both nitrogen and phosphorus) attached to sediment to overall nutrient loads affecting the offshore reefs.

Emerging research has identified that the fine fractions of soils leaving grazing, cane and other cropping lands are the most likely to reach and impact on reef systems, particularly in wider flatter reef catchments such as the Burdekin and Fitzroy catchments.

The Burdekin and Fitzroy catchments contribute at least 70 per cent to the modelled total suspended solids load reaching the reef lagoon from human activity. Grazing lands contribute more than three quarters of this load. Gully and stream-bank erosion (subsurface erosion) provide the larger component of coarse and fine soil particles deposited in inshore and outer systems.

Fine sediments from surface erosion are a smaller component but the bio-availability and dispersion of particulate nutrients attached to these sediments and their effects on long-term reef health is not fully understood. Critical knowledge gaps relate to better understanding the sources and landscape processes, especially the soil types most likely to generate fine sediment if not managed correctly, a finer scale understanding of sub-catchments and land-uses most likely to contribute loads; and characterisation of dispersion mechanisms such as flood plumes and re-suspension. This information would support prioritisation of investment into management responses across reef catchments for grazing, sugar cane growing, cropping and other land-uses. Given the sediment loads associated with grazing lands, the preference is to better prioritise investment within the sub-catchments of the Fitzroy and Burdekin, particularly in the Fitzroy where soil vulnerability and gully mapping is yet to be undertaken.

Grazing management response continues to be based on enhancing or maintaining good land condition, preventing the initiation and spread of gullies and loss of surface soil, and appropriately responding to existing gullies and stream-bank erosion (the latter a more critical issue for the Burnett Mary region).

The 2013 Scientific Consensus Statement suggested that further investigation was required into techniques for managing gully and stream bank erosion, including their economic viability and effectiveness. The technical guides to management practices need to be continually updated, in particular to include economic implications of practice uptake.

Enhanced information would support better prioritisation of investment within the sub-catchments of the Fitzroy and Burdekin, particularly in the Fitzroy where soil vulnerability and gully mapping is yet to be undertaken.

The grazing community urgently needs to have access to the most up-to-date information with which to make management decisions about land, such as groundcover levels and climate variability, to help improve production systems on grazing lands. Over the last few years, improved understanding of sediment management has been included in the grazing industry's Best Management Practice program and wider extension programs. The ongoing challenge is to integrate the implementation of grazing management practices and systems into a whole-of-business context where profitability and debt management impact the uptake of practice. This approach affects how information is disseminated so that it can be best used by graziers and their support networks.

Under the previous science program, extension products such as online Forage reports have been made available for on-property decision-makers and extension providers, providing information about seasonal ground cover comparison, rainfall and pasture and erodible soils. Having been developed for the Burdekin grazing systems, most of these reports can now be transferred to support grazing land management across Queensland. Investment to translate information and current science into extension tools such as Forage, PaddockGRASP, Vegmachine and Stocktake across Queensland is an urgent priority.

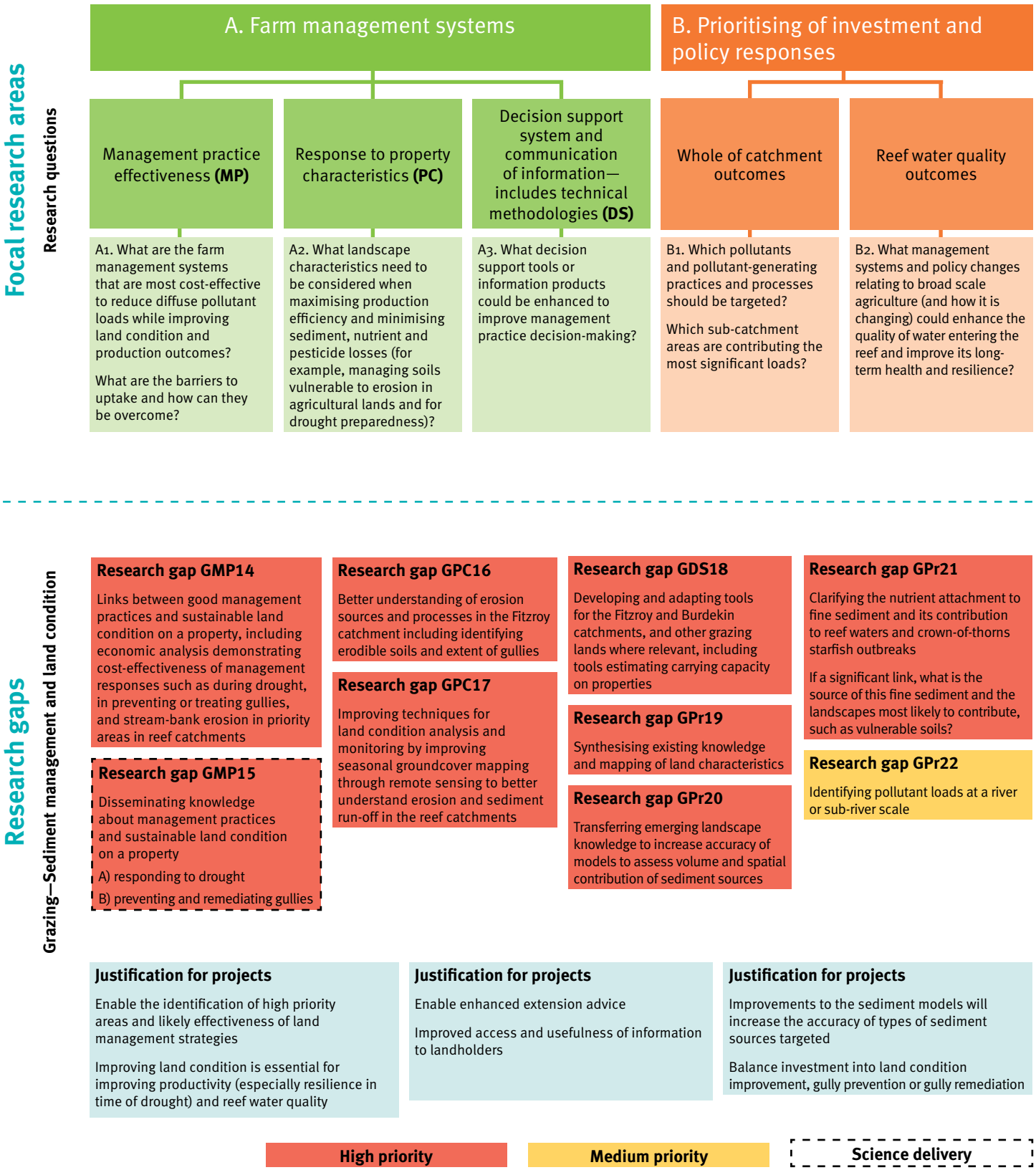
Table 4 lists the priority research gaps and priorities for grazing sediment management, and Figure 4 presents these gaps and priorities against the focal research areas of the RWQ RD&I Strategy.

Table 4: Research gaps and priorities for grazing sediment management and land condition

Research gap	Priority
GMP14 Links between good management practices and sustainable land condition on a property, including economic analyses demonstrating cost-effectiveness of management responses such as during drought, in preventing or treating gullies, and stream-bank erosion in priority areas in reef catchments	High
GMP15 Disseminating knowledge about management practices and sustainable land condition on a property a) responding to drought b) preventing and remediating gullies	High Science delivery*
GPC16 Better understanding of erosion sources and processes in the Fitzroy catchment including identifying erodible soils and extent of gullies	High
GPC17 Improving techniques for land condition analysis and monitoring by improving seasonal groundcover mapping through remote sensing to better understand erosion and sediment run-off in the reef catchments	High
GDS18 Developing and adapting tools for the Fitzroy and Burdekin catchments, and other grazing lands where relevant, including tools estimating carrying capacity on properties	High
GPr19 Synthesising existing knowledge and mapping of land characteristics	High
GPr20 Transferring emerging landscape knowledge to increase accuracy of models to assess volume and spatial contribution of sediment sources	High
GPr21 Clarifying the nutrient attachment to fine sediment and its contribution to reef waters and crown-of-thorns starfish outbreaks. If a significant link, what is the source of this fine sediment and the landscapes most likely to contribute, such as vulnerable soils?	High
GPr22 Identifying pollutant loads at a river or sub-river scale	Medium

*Science delivery indicates where there is a key gap in how the information is translated to the producers, leading to on-ground management practice change.

Figure 4: Reef Water Quality Science Program—grazing sediment management and land condition research gaps and justification



Theme 4. Bananas—managing nutrients, pesticides and sediments—Wet Tropics

More than 90 per cent of Australia's bananas are grown in the Wet Tropics region of North Queensland. Horticulture is the second highest contributor of anthropogenic dissolved inorganic nitrogen (DIN) from the Wet Tropics catchment, at around 10 per cent, the majority of this generated from banana crops.

There is a need for improved understanding around nutrient loss pathways in banana systems as the Scientific Consensus Statement 2013 attributes the elevated stream concentrations of nitrate to fertiliser application above plant requirements in sugarcane and bananas.

Current research identifies sediment losses from banana farm inter-rows as a priority (Armour, et al, 2014). Whilst sediment management in the Wet Tropics is not viewed as a high priority under Reef Plan, within the banana industry there is a need to better understand which management systems are required to keep sediment on property, along with attached nutrients and pesticides.

In 2012, the Banana Best Management Practices Environmental Guideline (Banana BMP) was developed; this is currently being rolled out by the Australian Banana Growers' Council (ABGC), in partnership with the Department of Agriculture, Fisheries and Forestry (DAFF) and supported by research funded under the Reef Rescue Program. This addressed nutrient, sediment and pesticide management. EHP is collaborating with the banana industry to support it in its endeavours to improve farming systems through its BMP and contribute to achieving targets under Reef Plan.

Critical to supporting banana growers is a better understanding of the cost and benefits of changing farming systems, similar to the information available for the cane and grazing industries. This is a gap in knowledge and hence a gap in extension services and decision support systems. Banana growers would also benefit from more information that explains how their activities impact on reef health.

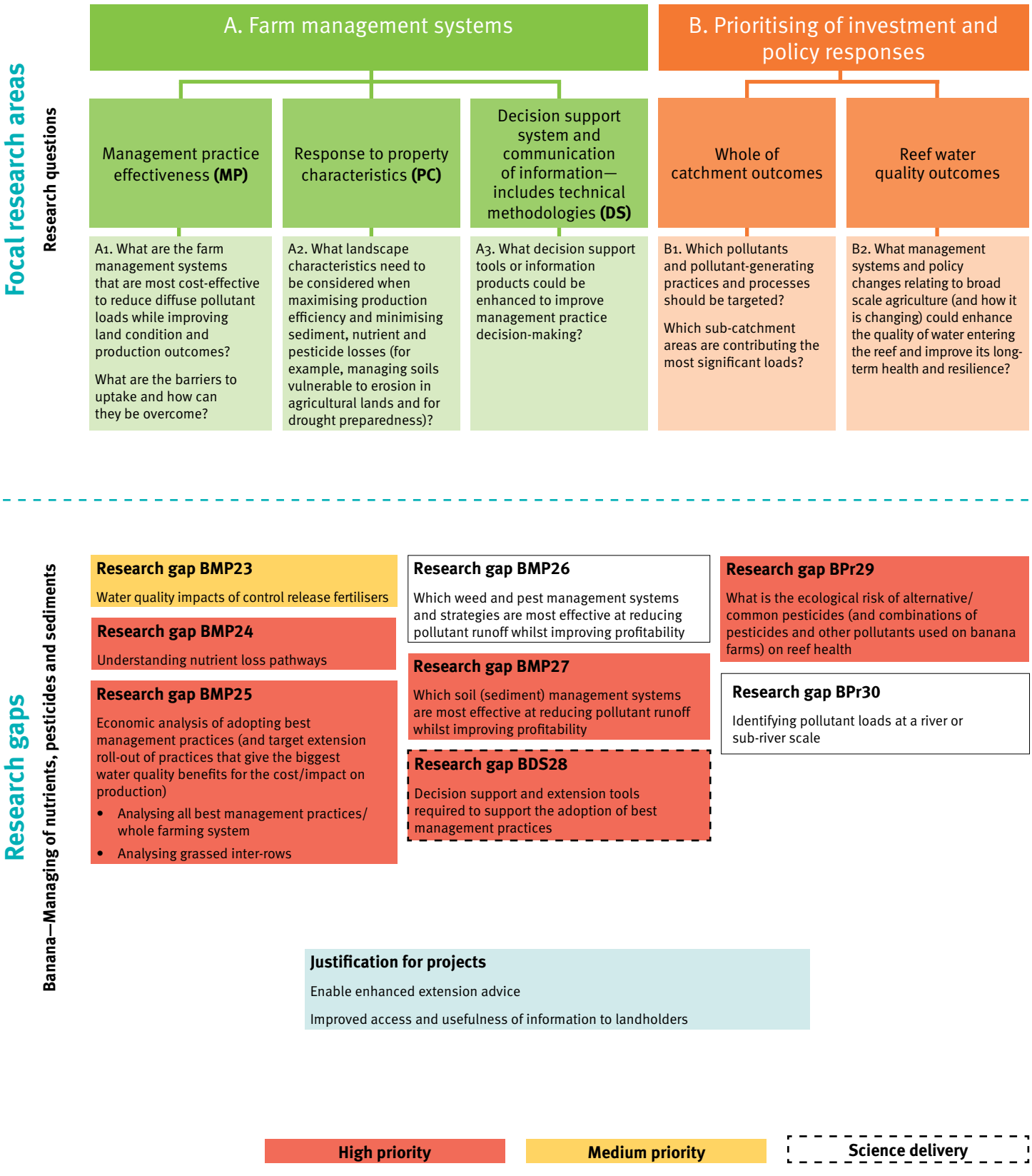
Table 5 lists the priority research gaps and priorities for bananas nutrient and sediment management, and Figure 5 presents these gaps and priorities against the focal research areas of the RWQ RD&I Strategy.

Table 5: Research gaps and priorities for banana—managing pesticides, nutrient and sediments—Wet Tropics

Research gap	Priority
BMP 23 Water quality impacts of controlled release fertilisers	Medium
BMP 24 Understanding nutrient loss pathways	High
BMP 25 Economic analysis of adopting best magement practices (and target extension roll-out of practices that give the biggest water quality benefits for the lowest cost/impact on production). • Analysing all best management practices/whole farming system • Analysing grassed inter-rows	High
BMP 26 Which weed and pest management systems and strategies are most effective at reducing pollutant runoff whilst improving profitability	Low
BMP 27 Which soil (sediment) management systems are most effective at reducing pollutant runoff whilst improving profitability	High
BDS 28 Decision support and extension tools required to support the adoption of best management practices	High Science delivery*
BPr 29 What is the ecological risk of alternative/common pesticides (and combinations of pesticides and other pollutants used on banana farms) on reef health	High/ Medium
BPr30 Identifying pollutant loads at a river or sub-river scale	Low

*Science delivery indicates where there is a key gap in how the information is translated to the producers, leading to on-ground management practice change.

Figure 5: Reef Water Quality Science Program—banana—managing nutrients, pesticides and sediments research gaps and justification



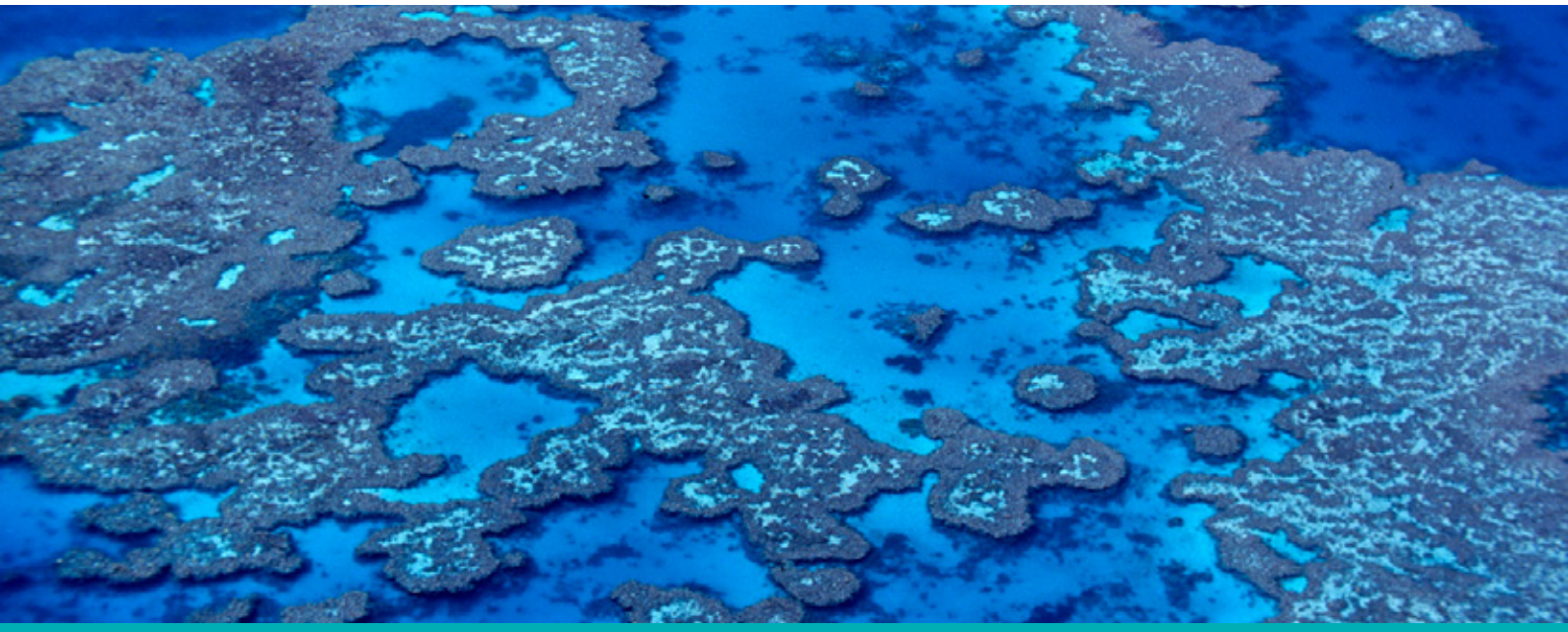
Conclusion

The Reef Water Quality Research, Development and Innovation Strategy will evolve in response to emerging issues and information. Several synthesis reports are being prepared, such as nutrient use efficiency, pesticides and sources of available particulate nutrients and organics. Where appropriate, the priorities identified in these reports will be reflected in this strategy.

Implementing the strategy relies on partnerships with other government departments and research organisations. Collaboration is essential to coordinate the response to address research gaps without duplicating effort.

For more information on the previous science program, and updates about implementing this strategy, visit www.qld.gov.au/environment/agriculture/sustainable-farming/reef

For information on Reef Plan visit www.reefplan.qld.gov.au



Appendix 1

Reef Water Quality Science Program—priority research questions

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
CANE—Nutrient use efficiency management—Wet Tropics and Lower Burdekin								
Research gap **CMP1** Effectiveness of nutrient management strategies and systems available to increase nitrogen (N) and phosphorus (P) use efficiency including economic viability								
1	Can the use of finer scale yield potentials based on farm/soil productivity zones or block yield potentials to calculate N requirements, improve nitrogen use efficiency and provide profitability, productivity and water quality outcomes?	✓	✓				High	C1, C2, C8
2	Can nitrogen use efficiency be improved by having specific nitrogen management strategies for zones with low nitrogen use efficiency? Specific nitrogen management strategies would consider: • soil characteristics under different climatic and manage ment scenarios • nutrient uptake and the conversion of nutrients into crop biomass • inherent soil constraints e.g. sodicity, waterlogging?	✓	✓	✓			High	C1, C2, C8
3	What is the most appropriate diagnostic test to determine available nutrients immediately prior to the last opportunity for fertiliser application to allow appropriate application rates to meet yield potential?	✓	✓	✓			High	C7

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **CMP2** Economic analysis of management practices for managing nutrients								
8	What is the cost effectiveness of practices to manage nutrients?							C3
Research gap **CPC3** Nutrient loss pathways and soil physical constraints to crop growth and management options to address those loss pathways and constraints.								
9	How effective are tail water pits in capturing and keeping nutrients on farm—sizes/designs etc?	✓					Med	
10	Accounting for nitrates in irrigation water	✓					Med	
Research gap **CDS4** Demonstrating the effectiveness of improved nutrient management practices and systems (including real time water quality monitoring)								
4	Water quality scenario modelling for cane management practices, including industry standards and modelling for block yield				✓		Med	
5	How can science-based decision support tools (e.g. SafeGauge) and associated extension advice be improved/developed in relation to: • the hierarchy of soil physical constraints to crop growth with management options to address those constrains • informing timing (in relation to weather, crop N status), placement, and N fertiliser form (e.g. controlled release fertiliser products to minimise N loss and maintain productivity and maximise profitability. This could be coupled with advice about the potential to reduce N rates where the effective growing season length has been reduced due to issues such as late harvest?	✓	✓	✓			Med–high	C16
6	Can climate forecasting tools be used to improve N use efficiency and estimation of yield potentials?	✓		✓			Low–med	
7	Can the demonstration of the effectiveness of improved nutrient management practices and systems (incl. real time water quality monitoring) increase the adoption of best practice?	✓		✓			Med–high	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **CPr5** Identifying pollutant loads at a river or sub-river scale								
11	Which sub-catchment areas (as fine a scale as possible) contribute the greatest proportion of DIN from cane lands at a river or sub-river level (as fine a scale as possible)?				✓		Med	
Research gap **CPr6** Synthesising knowledge about nutrient use efficiency								
12	What is the current level of knowledge regarding nutrient use efficiency? What knowledge gaps exist?						High	
CANE—Weed and pesticide management systems—Wet Tropics, Burdekin, Mackay-Whitsunday								
Research gap **CMP7** Which weed management systems and pesticide strategies are most effective at reducing pollutant runoff whilst improving profitability?								
13	Which weed management systems and pesticide strategies provide the best reef health, productivity and profitability outcomes across the various regions/ farming systems/climatic conditions?	✓					Med	C6, C10
14	How can science-based decision support tools (e.g. SafeGauge) and associated extension advice be improved/developed in relation to the ecological risk of pesticides to the GBR and minimising the loss of/ impact from pesticides on the GBR?			✓			Low	C16
Research gap **CMP8** Economic analysis of management practices for managing pesticides.								
15	What is the cost effectiveness of practices to manage weeds and associated weed application?						High	C3
Research gap **CDS9** Farmers' knowledge and understanding of labels and other legislative requirements for chemical use								
16	How can science-based decision support tools (e.g. SafeGauge) and associated extension advice be improved/developed in relation to the ecological risk of pesticides to the GBR and minimising the loss of/ impact from pesticides on the GBR?			✓			Med	C16
17	Can the demonstration of the effectiveness of improved weed/pesticide management practices and systems increase the adoption of best practice?	✓		✓			Med	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **CDS10** Extension of information relating to best management practices for profitability, productivity (science delivery) and water quality outcomes								
18	How can information related to economic best management practices be improved/developed?						Med	
Research gap **CPr11** What is the ecological risk of alternative/common pesticides (and combinations of pesticides and other pollutants) on reef and seagrass health?								
19	What is the ecological risk of pesticides in the GBR (including alternative and commonly used, their combination with each other and with other pollutants) and which pesticides have the lowest risk to the GBR based on their toxicity and run-off potential?					✓	High/ Med	C4, C5
Research gap **CPr12** Synthesising knowledge of impacts and management of pesticides								
20	What does the emerging published and unpublished literature and data say about: • pesticide use, particularly emerging products in the sugar cane industry in GBR catchments • the ecological risk of alternative/common pesticides (and combinations of pesticides and other pollutants) on reef health	✓			✓	✓	High	C4
Research gap **CPr13** Identifying pollutant loads at a river or sub-river scale, in priority areas from cane and other commodities								
21	What sub-catchment areas (as fine a scale as possible) contribute the greatest proportion of pesticides from cane lands at a river or sub-river level (as fine a scale as possible)?						Med	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Grazing—Sediment management and land condition —Burdekin and Fitzroy								
Research gap **GMP14** Links between good management practices and sustainable land condition on a property, including economic analyses demonstrating cost-effectiveness of management responses such as during drought, in preventing or treating gullies and stream-bank erosion in priority areas in reef catchments.								
22	What are the management practice systems of grazing enterprises that are productive, profitable and sustainable with good land condition and minimal sediment run-off? Which properties are most resilient and maintaining good land condition in high risk areas despite drought? (refer to emerging outcomes from RWQ science program 2011 to 2014 and other studies and on ground knowledge for high risk areas)?	✓	✓	✓			High	G1
22	What is the cost effectiveness of management responses e.g. during drought, restoration of degraded land, such as gully, scalded areas or eroded frontage country?	✓	✓	✓			High	G1
23	The delivery of knowledge through case studies could support industry and government programs that include economic analysis of systems, report on land condition during drought and recovery process/period of the same properties when/if it rains?	✓	✓	✓			High	G1
24	The delivery of knowledge through property demonstration sites that could be developed to demonstrate restoration of degraded land on productive land types?	✓	✓	✓			High	G1
25	How can economic components relevant to projects be incorporated to demonstrate cost effectiveness of management responses?	✓	✓	✓			High	G1
26	Can outcomes from existing projects inform this process?	✓	✓	✓			High	G1
Research gap **GMP15** Disseminating knowledge about management practices and sustainable land condition on a property a) responding to drought b) preventing and remediating gullies								
28	How can the outcomes from GMP14 (Links between good management practices and sustainable land condition on a property including economic analysis demonstrating cost effectiveness of management responses, e.g. during drought, in preventing/ treating gullies and stream-bank erosion in priority areas in Reef catchments) be extended to industry stakeholders?			✓			High	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **GPC16** Better understanding of erosion sources and processes in the Fitzroy catchment including identifying erodible soils and extent of gullies.								
29	What knowledge is available about the erodible soils in the Fitzroy (especially soils that are most likely to contribute to sediment run-off when land condition is poor)? How can it be ensured that methodology is consistent with RWQ studies in the Burdekin?		✓		✓	✓	High	G6
30	What knowledge is available on the density of gullies in the Fitzroy? How can it be ensured that methodology is consistent with the recent RWQ gully mapping in the Burdekin?		✓		✓	✓		
31	What knowledge is available about ground cover in the Fitzroy and how can it be addressed to ensure knowledge is consistent with the Burdekin?		✓		✓	✓		
32	What knowledge is available with respect to sediment tracing in the Fitzroy and should it be addressed to ensure knowledge is consistent with the Burdekin?		✓		✓	✓		
33	How can outcomes from sediment, erodible soils, gullies and ground cover mapping be used to guide policy and extension planning?			✓	✓	✓		
Research gap **GPC17** Improving techniques for land condition analysis and monitoring by improving seasonal groundcover mapping through remote sensing to better understand erosion and sediment run-off in the reef catchments.								
34	Can remote sensing and related technologies be extended to help in: a. improve the uncertainty in ground cover estimates in areas of high tree cover b. identify of B and C land condition in the whole of reef catchments, in particular Burdekin and Fitzroy?		✓		✓		High	G8

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **GDS18** Developing and adapting tools for the Fitzroy and Burdekin catchments, and other grazing lands where relevant, including tools estimating carrying capacity on properties.								
35	Is there a need to revisit technical guides for best management practices in the Burdekin and/or Fitzroy for productivity, profitability and water quality? e.g. Update John McIvor's technical guide 2012 *Sustainable management of the Burdekin grazing lands—a technical guide of options for stocking rate management, pasture spelling, infrastructure development and prescribed burning to optimise animal production, profitability, land condition and water quality outcomes* Update technical guide 2010 *Best-bet practices for managing the grazing lands of the Fitzroy Woodlands—a technical guide of options for optimising animal production, profitability and land condition* Is there a need to scope/develop a technical guide grazing for the Burnett-Mary?	✓		✓	✓		High	G1 G12
36	What further package development and ground truthing is needed before PaddockGRASP can be rolled out in the Burdekin?							
37	What adaptions/ground truthing is needed for PaddockGRASP and Forage reports (Burdekin) before they can be rolled out in the Fitzroy?							
38	What extension and education (E&E) tools and resources are needed to optimise the use of products developed from projects e.g. what training is needed before PaddockGRASP can be used for decision making by graziers?	✓		✓			High	
39	What range of tools provide information, including maps, climatic data and 'what if' scenarios on carrying capacity for properties are available, and how can they best be used for optimum benefit? Tools include: • PaddockGRASP, Vegmachine online • FORAGE reporting • Spatial hub development?		✓	✓			High	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **GPr19** Synthesising existing knowledge and mapping of land characteristics								
40	What is the current knowledge about sediment and its management in the Burdekin?	✓		✓	✓		High	G6
41	What is the current knowledge about sediment and its management in the Fitzroy?	✓		✓	✓		High	G6
42	How can existing knowledge be packaged to ensure dissemination of outcomes, e.g. prioritisation tool is included in water quality improvement plans (WQIPS) for the Burdekin and Fitzroy?	✓		✓	✓		High	G6
Research gap **GPr20** Transferring emerging landscape knowledge to increase accuracy of models to assess volume and spatial contribution of sediment sources.								
43	What needs to be done to ensure that outcomes from sediment, soils, ground cover and gullies studies are used to enhance Paddock2Reef models?			✓	✓		High	
Research gap **GPr21** Clarifying the nutrient attachment to fine sediment and its contribution to reef waters and crown-of-thorns starfish outbreaks. If a significant link, what is the source of this fine sediment and the landscapes most likely to contribute, such as vulnerable soils?								
44	What is the evidence that nutrients (N and P) are attached to fine sediments?		✓		✓	✓	High	G7
45	What and where in the catchments (and across commodities) are any such sediments and nutrients coming from?		✓		✓	✓	High	G7
Research gap **GPr22** Identifying pollutant loads at a river or sub-river scale.								
46	Which sub-catchment areas (as fine a scale as possible) contribute the greatest proportion of sediment from grazing lands at a river or sub-river level (as fine a scale as possible)?						Med	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Bananas—Managing nutrients, pesticides and sediments—Wet Tropics								
Research gap **BMP 23** Water quality impacts of controlled release fertilisers								
47	Are there water quality benefits of using control release fertilisers? What are the water quality benefits of using control release fertilisers? What is the strategy for using control release fertilisers that delivers the greatest water quality benefits?	✓					Med	
Research gap **BMP 24** Understanding nutrient loss pathway								
48	In banana farming practices, what are the key nutrient loss pathways? Which banana farming practices minimise the loss the nutrients?	✓					High	
Research gap **BMP 25** Economic analysis on the financial benefit of adoption of best management practices (and target extension roll-out of practices that give the biggest water quality benefits for the cost/impact on production) • Analysing all BMP practices/whole farming system • Analysing grassed inter-rows								
49	What are the economic impacts of adopting best management practices? Which whole of farming systems are economically beneficial for bananas?	✓					High	
Research gap **BMP 26** Which weed and pest management systems and strategies are most effective at reducing pollutant runoff whilst improving profitability								
50	Which weed and pest management systems and strategies are most effective at reducing pollutant runoff whilst improving profitability?	✓					Low	
Research gap **BMP 27** Which soil (sediment) management systems are most effective at reducing pollutant runoff whilst improving profitability								
51	Which soil (sediment) management systems are most effective at reducing pollutant runoff whilst improving profitability? What is the effectiveness of grassed inter-rows in reducing sediment runoff?	✓	✓				High	

RWQ Question number	Priority research questions	Farm management systems			Prioritisation of investment and responses		Priority	Relevant Reef Plan RD&I Question no.
		Management practice effectiveness	Response to property characteristics	DSS and communication of information (incl technical methodologies)	Whole of catchment outcomes	Reef water quality outcomes		
Research gap **BDS 28** Decision support and extension tools required to support the adoption of best management practices								
52	How can information related to economic best management practices be improved/developed?						High	
Research gap **BPr 29** What is the ecological risk of alternative/common pesticides (and combinations of pesticides and other pollutants used on Banana farms) on reef health?								
53	What is the ecological risk of pesticides in the GBR (including alternative and commonly used, their combination with each other and with other pollutants) and which pesticides have the lowest risk to the GBR based on their toxicity and run-off potential?	✓					High/ Med	
Research gap **BPr 30** Identifying pollutant loads at a river or sub-river scale								
54	Which sub-catchment areas (as fine a scale as possible) contribute the greatest proportion of nutrients, pesticides and sediment from banana lands at a river or sub-river level (as fine a scale as possible)?	✓		✓	✓		Low	