CLIMATE SUSTAINABILITY PLAN 2016-2020

MACKAY ▪ WHITSUNDAY ▪ ISAAC

Australian Government

National Landcare Programme

REEF CATCHMENTS

Acknowledgments: Reef Catchments gratefully acknowledges report authors Robyn Bell and Cath Moran, 2016 Climate Sustainability Plan for the Mackay Whitsunday Isaac region 2016-2020.

Image: Katherine Sellers, runner-up Reef Catchments Coastcare photo competition 2016.

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We gratefully acknowledge the contributions that many regional stakeholders have made in the development of this plan. We also acknowledge important input from Reef Catchments staff, as well as CSIRO and James Cook University partners. Development of this plan was supported by funds from the Australian Government's NRM Planning for Climate Change fund, as well as the National Landcare Programme.

EXECUTIVE SUMMARY

Development of this Climate Sustainability Plan was supported by the Australian Government's NRM Planning for Climate Change fund. Reef Catchments was tasked with identifying priority areas for achieving carbon sequestration and biodiversity benefits in the context of climate change. It was expected that this would be based on collaboration with scientists and engagement with regional stakeholders.

This Plan sets out the most recent and regionally specific projections for rainfall, temperature, sea level rise and other climatic changes. The science shows us that while average climate patterns may not change dramatically in the Mackay Whitsunday Isaac (MWI) region, extreme events are likely to become more intense and more frequent. The MWI region is already subject to flooding, storm surge and cyclones which incur significant economic and social costs.

This Plan takes a preliminary look at likely impacts and potential adaptation opportunities associated with climate changes. Specifically, this Plan considers issues around the availability and supply of fresh water, sustainability of industries, maintenance of healthy communities, the protection of natural systems and management of invasive species.

Natural systems have the least capacity to adapt to projected climate changes, meaning that particular effort will be needed to protect plants, animals and their habitats in the region. The supply of fresh water is also likely to be seriously challenged by increased evaporation, changes in rainfall and sea level rise. All of the regions' communities and industries will be impacted, requiring substantial changes in production, management practices, emergency services, and even the location of some human settlements.

This Plan documents strategies and specific actions, identified through extensive consultation with regional stakeholders, that are aimed at adapting to these challenges. Implementation of these strategies and actions will require integration with other strategies, programs and initiatives within Reef Catchments, with all levels of government, with industries, research organisations and other stakeholder groups.

The current policy context is uncertain and complex, but there is substantial motivation across most sectors in the MWI region to develop better understanding of the impacts of climate change, and to negotiate adaptation pathways that lead to a sustainable future for the region. This Plan represents the first, important step in what will be an ongoing process of working together to adapt to substantial and unprecedented change in our region.

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CHAPTER 1

Project Background

In 2012, the Australian Government committed $44 million to the Regional NRM Planning for Climate Change Fund (Australian Government, 2013). This funding was designed to support regional Natural Resource Management (NRM) groups throughout Australia to update their NRM plans using new regionally synthesised science products. These products support adaptation responses to climate change and guide climate change program actions and impacts on-the-ground, and maximise the environmental benefits of carbon farming projects (Bohnet et al., 2013; Australian Government, 2013).

Two streams of funding were provided under the program: Stream 1 to support regional NRM organisations across Australia to update their NRM plans for adaptation to climate change impacts. Stream 2 supported coordination of research (Parts A and B) to develop scientific information on climate change at the national and regional level, and to generate new knowledge and tools required to develop new adaptive NRM plans.

Australia's 56 NRM regions were grouped into eight clusters based on broad similarity in climate, landscape and socio-economic characteristics through which the research was delivered (see Figure 1.1). The Mackay Whitsunday Isaac (MWI) NRM region is part of the Wet Tropics Cluster that also included the Wet Tropics (Terrain NRM), Cape York (Cape York NRM) and the Torres Strait region (Torres Strait Regional Authority -TSRA).

Projects to support the planning process included:

- Delivery of Climate Projections (CSIRO/ Bureau of Meteorology) specific to the eight clusters (Figure 1.1)
- AdaptNRM. Tools and resources to support climate adaptation planning which has delivered modules on planning, weeds, and biodiversity http://adaptnrm.csiro.au/about-adaptnrm/
- Terranova. A central long-term data repository hub for access to all research, tools and resources developed through the program https://terranova.org.au/about
- Regional research support. The MWI NRM region has been a part of the Wet Tropics Cluster supported through James Cook University and CSIRO.

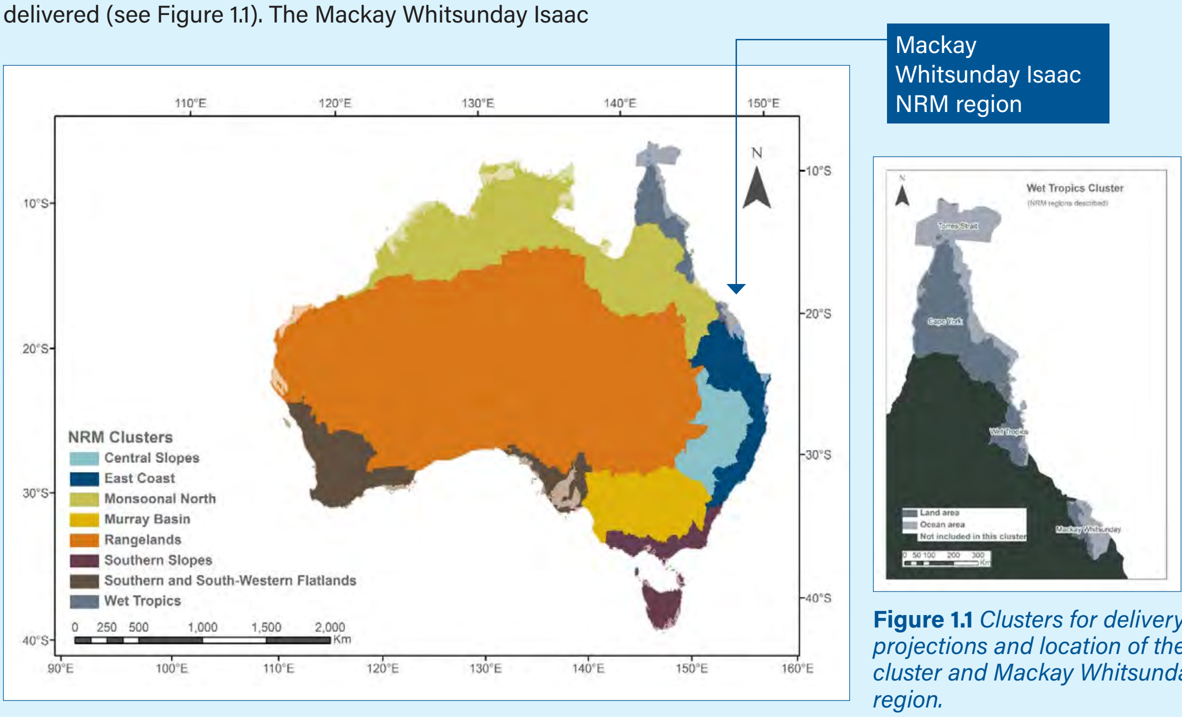


Figure 1.1 *Clusters for delivery of climate projections and location of the Wet Tropics cluster and Mackay Whitsunday Isaac NRM region.*

Wet Tropics Cluster co-research approach

The James Cook University (JCU) and CSIRO research consortium used a co-research approach to delivering the project *Knowledge to manage land and sea: A framework for the future* in the Wet Tropics Cluster. The co-research approach undertaken in the Wet Tropics Cluster brings together researchers with different scientific backgrounds as well as NRM planners and managers from the four NRM agencies to make collaborative decisions about research direction, the allocation of project resources, and long-term science-planning partnerships in the region. Central to the approach was the establishment of a Brokering Hub with representatives from research and practice disciplines (Figure 1.2). This co-research approach draws on the growing evidence that transdisciplinary research methods are of critical importance to solving sustainability problems and achieving climate adaptation (e.g. Jahn et al., 2012; Lang et al., 2012).

The Brokering Hub consisted of two project co-leaders (CSIRO and JCU), a project Knowledge Broker who coordinated and managed the activities of the Wet Tropics Cluster, representatives from each of the four regional NRM agencies, researchers representing three science nodes and the national project team. The three science nodes were: (1) science synthesis, (2) participatory scenario and knowledge integration, and (3) prioritisation and opportunities (Figure 1.2).

Developing Reef Catchments Climate Sustainability Plan

Reef Catchments commenced updating their NRM Plan prior to release of the Stream 1 funding, and it was released in February 2015. The completed MWI NRM Plan contains agreed outcomes and management actions for protecting and restoring the region's natural assets. *This Climate Sustainability Plan* supports updates to the MWI NRM Regional Plan (Reef Catchments, 2014a) which identifies climate change as one of the region's issues. A number of the outcomes from the stakeholder engagement process (see Chapter 2) that have been used to develop this Plan were incorporated into the NRM Regional Plan, but are further developed into specific and spatially explicit priority actions.

The process used in development of the Climate Sustainability Plan acknowledged that climate change is not the only change the regional community is experiencing. This approach is also consistent with that of the Intergovernmental Panel for Climate Change (IPCC). The 2007 IPCC AR4 synthesis examined coping range, adaptive capacity and vulnerability of various sectors in the Australian and New Zealand context (Figure 1.3).

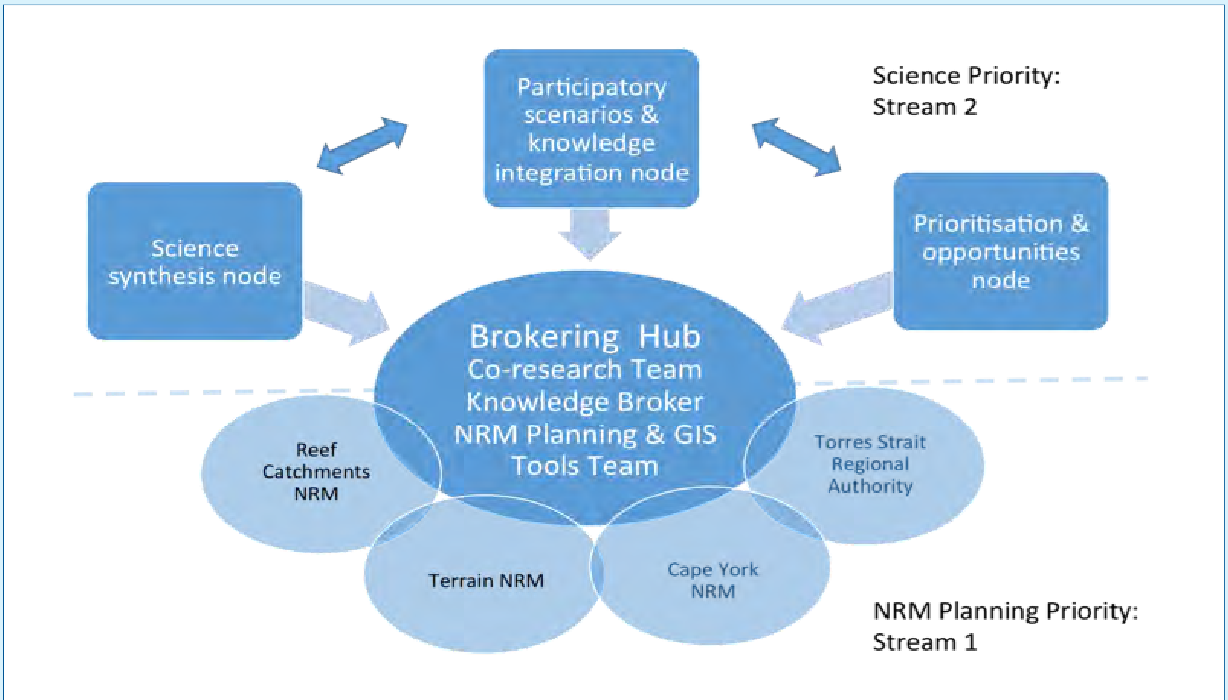


Figure 1.2. *Co-research approach that promoted through collaboration and co-research, in the formation of the Wet Tropics cluster (Source: Bohnet et al., 2013).*

Figure 1.3 shows that natural ecosystems are identified as having the highest vulnerability and least capacity to adapt to ongoing temperature change. Water security and coastal communities (such as the MWI NRM region) are also highly vulnerable in this context. Impacts on other sectors are also likely to be serious, but in many cases, their vulnerability is lower and adaptive capacity higher.

Consistent with the Australian Government's NRM Planning for Climate Change program, Reef Catchments' *Climate Sustainability Plan* has been developed using the following three key NRM planning principles:

i. Plans identify priority landscapes for carbon plantings and strategies to build landscape integrity and guide adaptation and mitigation actions to address climate change impacts

ii. Planning process is logical, comprehensive and transparent

iii. Plans use best available information to develop actions and are based on collaboration with government, community and other stakeholders

The process used to develop this *Climate Sustainability Plan* has been logical, comprehensive and transparent (principle ii., above), using a participatory planning process to collaborate with stakeholders and work with scientists. This has involved an iterative process of different forms of engagement with government, community and other stakeholders, as well as collaboration with scientists to develop and access best available information (Principle iii., above). While there are some stakeholders who did not engage in the process, wide representation from a diversity of stakeholder groups was achieved. The plan identifies priority landscapes for carbon plantings and strategies to build landscape integrity (consistent with principle i., above; described in Chapter 6). Transparency has been achieved through the presentation and discussion of scientific information in a range of freely-available formats, as well as the documentation of results from engagement processes, and circulation of workshop reports to participants.

Many concerns were expressed about gaining effective engagement during the project, due to changes in policy and the resulting uncertainty among stakeholders in relation to State and Federal government commitment and support. This was compounded by portrayal of uncertainty in the media around the validity of climate change science and potential negative impacts on the economy. In an attempt to address these barriers to engagement around issues relating to climate change, the process acknowledged that 'climate change is not the only change society is experiencing.' Engagement focused on the key drivers of change that impact on the regional community, providing a pathway for stakeholders to develop priority strategies and actions that worked towards social, cultural, environmental and economic sustainability in a changing climate.

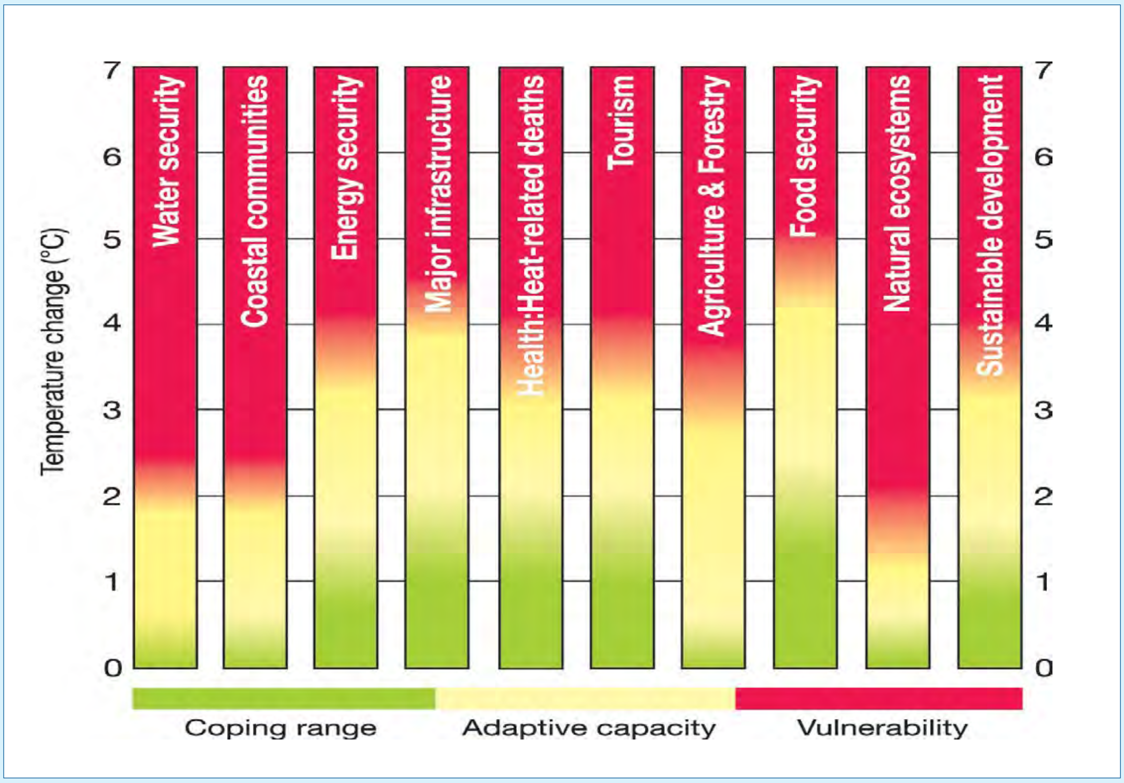


Figure 1.3 *Coping range, adaptive capacity and vulnerability of issues in the Australian and New Zealand context (Source: Adapted from IPCC 2007a Figure 11.4)*

CHAPTER 2

The participatory planning process

This chapter provides an outline of the participatory processes used to develop Reef Catchments' Climate Sustainability Plan. These processes emphasised participation from Traditional Owners, a wide range of regional NRM stakeholders and Reef Catchments staff. This process aimed to record their aspirations and values as well as to develop practical strategies and actions. The process also involved partnership with scientists, to ensure integration with community-led and science-led priorities.

The supporting document to this Plan *'Participatory Processes used to support development of the Climate Sustainability Plan'* describes how the process was framed, how a wide range of stakeholders were engaged in the process, and how best available information was developed and incorporated into the process (Appendix 3). This chapter provides a summary of outcomes from the stakeholder workshops and other engagement processes. Chapter 5 of this plan documents the priority landscapes and strategies identified through these processes.

Key events in the timeline of stakeholder engagement are depicted in Figure 2.1, below.

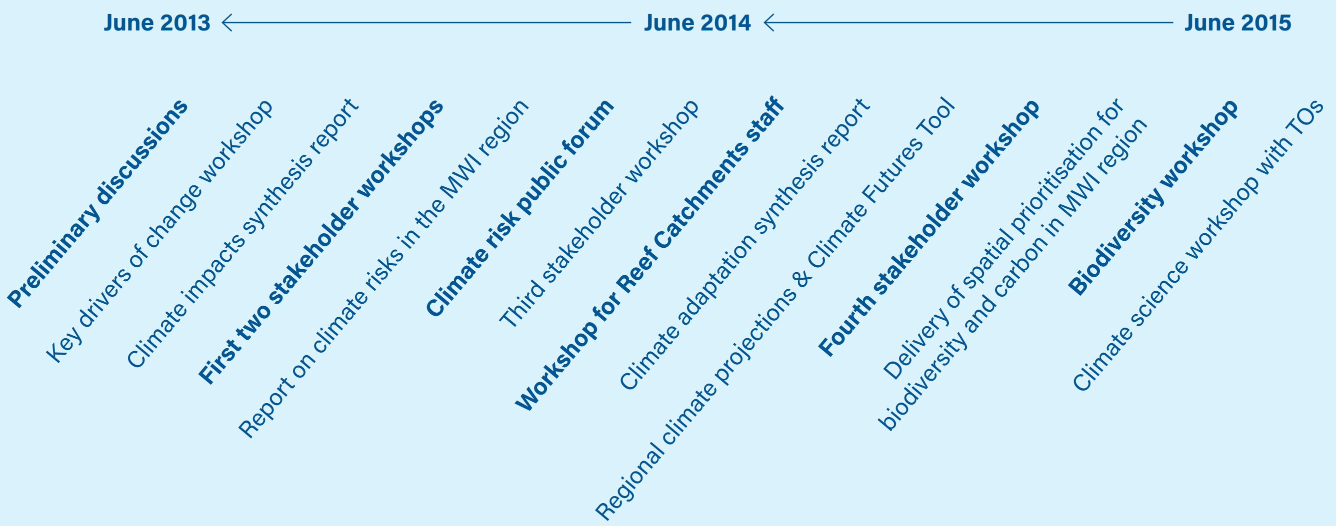


Figure 2.1 *Indicative timing of major stakeholder engagement activities, together with the delivery of key supporting resources and tools*

The conceptual framework for working through multi-stakeholder workshops is shown in Figure 2.2. Workshops predominantly used 2030 as a target year to focus future-oriented discussion, though different time frames were also considered in presentations and discussions, and climate change projections were characterised in terms of the 4.5 (business as usual) and 8.5 representative concentration pathways (RCP).

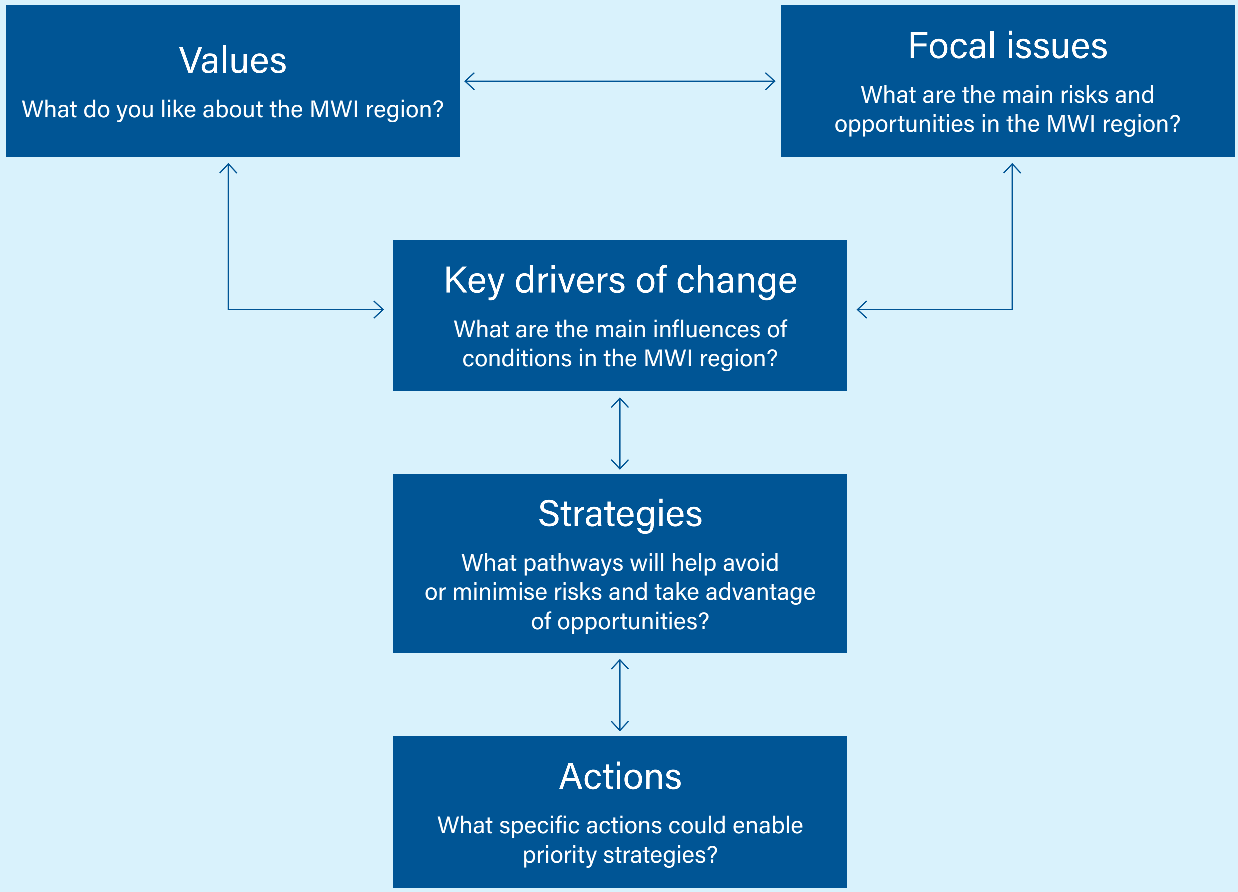


Figure 2.2 *Conceptual framework for the multi-sectoral stakeholder workshop series.*

Workshops achieved diverse, multi-sectoral stakeholder representation, including:

- Planning and emergency services staff from the Whitsunday, Mackay and Isaac Regional Councils
- Indigenous groups, i.e. the Yuibera Aboriginal Corporation and Yuibera, Koinmerburra and Ngaro-Gia Traditional Owners;
- Agricultural industries, i.e. Cane growers, graziers, Plane Creek & Mackay sugar mills, AgForce, GrowCom; sugar productivity services
- Tourism sector
- Mining (Anglo-American Coal)
- Non-governmental organisations (NGO's), i.e. Landcare, Turtle Watch, Mackay Conservation Group, Community gardens
- Agriculture and Fisheries (QDAF), Department Natural Resources and Mines (DNRM), Education Queensland and The Department of State Development (SD)
- Great Barrier Reef Marine Park Authority (GBRMPA)
- Regional Development Australia
- Recreational fishers
- Steel Pacific Insurance Brokers.

Efforts were made also to engage with North Queensland Bulk Ports (NQBP), Regional Development Australia (RDA) and community health organisations. However these efforts were not successful in gaining their involvement in the process. NQBP did participate in the community forum on climate risk. Workshop activities were intentionally designed to integrate representation from different sectors. Information about priority values, key threats and potential strategies was developed during the workshop.

Outcomes of the participatory planning process

Reports provide more detail about the content and outputs of the various workshops (Bell et al., 2014a, b; 2015). These were circulated to stakeholder and researcher participants for comment after the workshops. This section, identifies the key values from the stakeholder workshops and the related drivers of change and key issues. Secondly, this section identifies the principles that emerged from the multi-sectoral stakeholder engagement processes, together with those identified in the supporting science. These principles are based on a combination of Values, Drivers of change and Focal issues (see Figure 4.2 above).

A collective vision for the future

A range of values and focal issues were identified during stakeholder workshops. These are attributes that the stakeholders either would like to preserve (values) or change (focal issues) as part of a preferred vision for the future. Together, these are key elements of a collective vision for the future of the MWI region. Those that were agreed across multiple stakeholders included:

a. The ‘sense of community’; small-town feel, non-commercialised; cultural and social diversity

b. Resilient communities, including in relation to extreme weather

c. Diversity of natural landscapes, e.g. reef and ranges

d. Access to good services and infrastructure such as schooling, pools, airports

e. Food security

f. Water security

g. Agreeable climate and weather.

Discussions during workshops identified the following four key drivers of change that are likely to have the most influence over the collective vision for the future of the MWI region. These are:

Rapidly increasing population: it is projected that the current population will grow by 47% by 2031 (Binney, 2014). Much of the recent increase is attributable to the mining ‘boom’ in the region. A major concern is the past and potential future loss of good agricultural land (and hence, viability of some industries) from loss to urban/suburban development. *Affects a)-f).*

Community capacity: the MWI population in general is characterised by having relatively low levels of education but relatively high income (Reef Catchments, 2104). This is attributed largely to the legacy of the mining industry in the region. Many community organisations e.g. Landcare, depend on Volunteers but many of these are ageing. Also, large number of shift-workers (especially, but not only, in mining industry) with limited capacity for community involvement. Existing processes for consultation sometimes perceived as token. Apathy. Traditional Owners. *Affects b) especially*

Economic conditions: It is generally perceived that there is a lack of diversity in the region’s economy. Overall economic conditions in the region are determined by the mining industry, with cyclical ‘boom-and-bust’ characteristics in mining and related industries such as construction and retail, and a lack of strength in other sectors. The relative economic importance of agriculture in the region has decreased, as has the availability of agricultural labour and this affects succession planning on farms. It was also pointed out that mining has increased the rate base in the region, improved services and infrastructure, and created new employment opportunities, though these have been shown to be transient with the recent downturn in resources. A major impact of mining has been dramatically reduced affordability of housing Affects a)-f)

Climate change: It is well-recognised that the MWI region is already one of very high climate variability. The impact of projected climate changes, particularly extreme events, will strongly affect the collective vision for the future of the region. Natural disasters already have major impacts on the MWI region and small changes in the mean climate can dramatically increase the occurrence of extreme events. Affects b), e)-g).

Note that the key drivers identified in multi-stakeholder workshops closely match those identified in the Brokering Hub workshop (Section 1.i). In the stakeholder workshop, government policies are recognised as critical but, instead of being a separate driver of change, were conceived as being embedded within each of the other drivers of change. In Table 2.1. key drivers of change are shown, together with the elements of the collective vision they most influence, and the strategies identified for managing this influence.

Table 2.1. *A summary of outputs from the multi-stakeholder workshop series. The seven basic elements of the collective vision described for the MWI region are listed. Key drivers of change are shown in relation to the elements of the collective vision they most influenced (unshaded areas). Related strategies are listed in the far right column.*

Key drivers of change				Collective vision	Related strategies
Community capacity	Climate change	Economic conditions	Increasing population		
				The 'sense of community'	• Collaboration • Traditional Owner involvement
				Diversity of natural landscapes	• Strategic planning • Biodiversity
				Access to services and infrastructure	• Strategic planning
				Food security	• Strategic planning • Diversified industry
				Water security	• Strategic planning • Diversified industry
				Resilient communities	• Collaboration • Community education • Traditional Owner involvement • Strategic planning • Diversified industry
				Agreeable climate and weather	• Strategic planning

In addition to the work done through multi-stakeholder workshops, the work conducted with Traditional Owners identified some key issues of importance, including access to country, the importance of fresh water and wetlands, protection and conservation of important cultural species and sites (e.g. fish traps and shell middens), camps on country and employment of the mob to look after country, revegetation and replacement of important plants, and monitoring and reporting health of country. The mapped climate risks are projected to increase with extreme weather events. The third stage was the involvement of the Traditional Owners in the regional multi-stakeholder climate adaptation workshops where they presented some of the activities undertaken in the project, highlighted the values they hold for country and the priorities issues they want to address.

SUMMARY

A large number of opportunities were provided to facilitate participation by stakeholders in the process of developing this plan. These included one-on-one meetings, focused work with particular groups or sectors and large, cross-sectoral stakeholder workshops. It has been particularly important that engagement with TO's, respects and acknowledges their responsibility to land and sea country. In general terms, participatory processes centred on the identification of values and aspirations, development of understanding of key threats to these, and formulation of actions and strategies to address these threats. The outcomes of this process represent a solid starting point for further discussion about specific adaptation pathways for the MWI region.

CHAPTER 3

Climate Change projections for the MWI NRM region

Weather, Climate Variability and Climate Change

The terms weather and climate are often used interchangeably; however weather, climate variability and climate change refer to different things in climate science. A brief explanation is given below.

The *Weather* experienced on a day-to-day basis is a result of the constant changing state of the atmosphere. Weather is characterised by the temperature, wind, rain, clouds and other weather elements (IPCC 2007a) such as cyclones. Typically, climate defines the average weather over a period of time, generally a minimum of 20 years.

Climate Variability refers to the variability in general climate patterns that occur over time. The average climate of summer is warmer than winter, but seasons vary from year to year with some summers hotter or wetter than others in different years and winters that may be cooler or drier in a certain year. Climate drivers that influence climate variability are a result of interactions between the ocean and the atmosphere, e.g. the El Niño Southern Oscillation (ENSO) plays a large role in climate variability from year to year.

Climate change is a change in the state of the climate that can be identified by changes in the mean and/ or variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2007b).

The timescales on which weather, climate variability and climate change are shown in Figure 3.1.

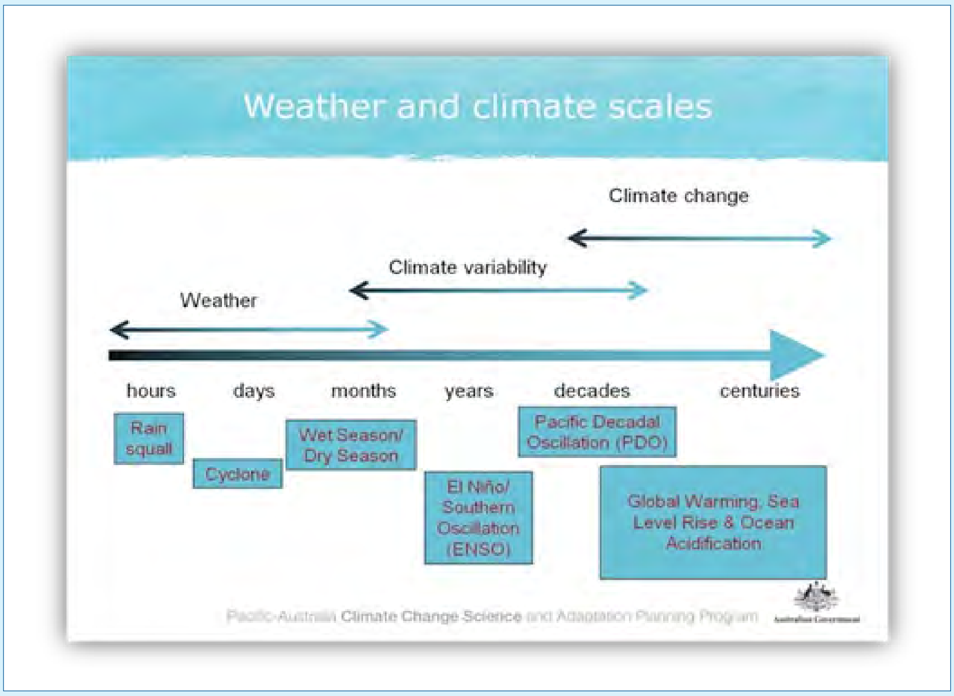


Figure 3.1 *Time scales of weather, climate variability and climate change.*
Source: http://www.pacificclimatefutures.net/en/help/climate-projections/understanding-climate-variability-and-change/

Climate drivers in the MWI NRM region

The Australian continent has the largest rainfall (and climate) variability in the world. The drivers of climate variability for Australia are described in the climate projections report (CSIRO and Bureau of Meteorology 2015) and are categorised via tropical and extratropical modes (weather features). The MWI region however, has higher climate variability (Nicholls et al. 1997) than the other NRM regions in the cluster (Wet Tropics, Cape York and Torres Strait) and there may be some influences from extra-tropical modes for the region's climate that are yet to be clarified by climate scientists. Most information provided in this section has been sourced from the CSIRO and Bureau of Meteorology (2015) climate projections report.

The regional climate varies significantly with wetter parts of the region (i.e. Finch Hatton) to drier areas such as Eton. The regional climate is influenced by local and regional land surface characteristics that influence moisture and energy (solar radiation) exchange with the atmosphere (Sturman & Tapper 2005). The direct influence at particular locations needs longer term monitoring to improve understanding of variations and influences within the region. Sturman and Tapper (2005) is an excellent reference to improve understanding of weather and climate drivers in Australia including regional and temporal scale influences.

There are two Bureau of Meteorology meteorological stations that monitor climate within the region: Mackay (Latitude 21.12°S – Longitude 149.22°E – Elevation 30m) and Proserpine airport (Latitude 20.49°S – Longitude 148.56°E – Elevation 20m). Climate scientists have made significant advances in understanding weather and climate processes but these tend to focus on the influence of larger-scale processes or drivers and the parts of the continent that they influence. The rest of this chapter focuses on the larger scale processes that are known to influence the region's climate..

The weather and climate features that affect climate variability in Australia are shown in Figure 3.2.

Two distinct seasons (wet and dry) occur in northern Australian tropical modes (CSIRO and Bureau of Meteorology (2015). These are influenced by the Australian monsoon, but influence of the monsoon is stronger in the northern parts of the Wet Tropics cluster and has less of an influence in the MWI region. Onset of monsoon breaks is partly determined by the Madden-Julian Oscillation (MJO), which is an eastward moving tropical disturbance of high convection and rainfall with an average frequency of 40-50 days.

The main drivers of natural tropical climate variability: the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) influence timing of the Monsoon and MJO from year to year.

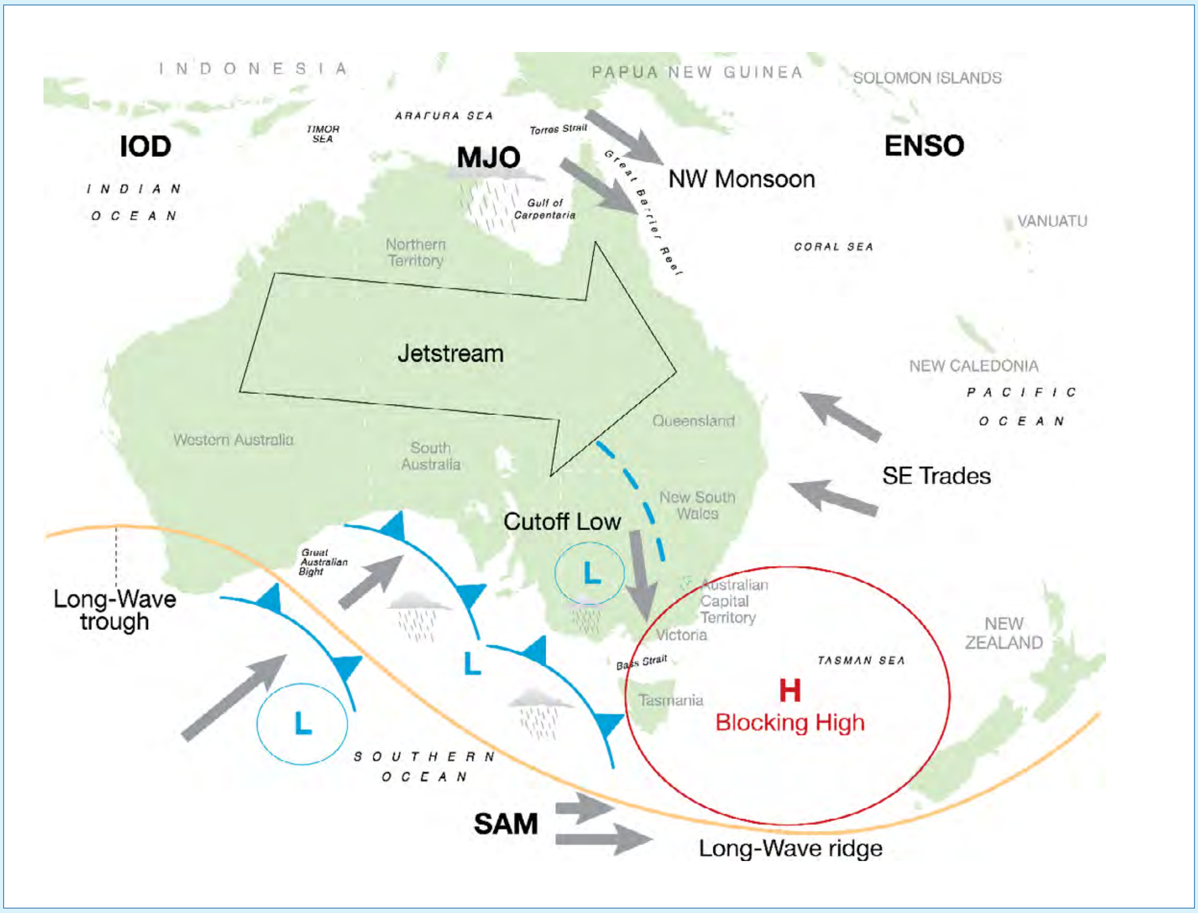


Figure 2.2 *The main weather and climate features affecting climate variability in Australia. (Source: Risbey et al. 2009 cited by CSIRO and Bureau of Meteorology 2015)*

ENSO is a major driver of global inter-annual climate variability and has three phases (neutral, El Niño and La Niña) that are based on anomalies of sea surface temperatures (SST) along the equator in the Pacific Ocean. The ENSO dominant neutral phase occurs when SST and trade winds are in balance. The El Niño phase occurs when the trade winds along the equator lessen and SST are higher than normal in the eastern Pacific (and cooler over northern Australia), which brings reduced rainfall to eastern Australia. The La Niña phase occurs when trade winds strengthen, SST's are lower than average in the eastern Pacific and higher over northern Australia. La Niña is associated with higher than average rainfall over eastern Australia, with increased risk of tropical cyclones.

The IOD is a feature of the equatorial Indian Ocean characterised by changes in SST that affect year to year climate variability across Australia and is broadly correlated with rainfall across central and southern Australia (Risbey et al. 2009). The influence of the IOD to the climate of the MWI region is not clear. For further information about ENSO phases and the IOD see Chapter 4 in CSIRO and Bureau of Meteorology (2015).

Understanding of the weather and climate has progressed rapidly over the last 30 years, however many studies have examined climate drivers in isolation from each other and at larger scales than specific NRM regions. The extent of influence of these drivers and their interactions is also likely to change on a yearly, decadal or longer-term basis. Drivers of climate in the extra-tropical regions of Australia (Southern Annular Mode, Subtropical Ridge, etc.) may or may not influence the local region. Further information on the current state of knowledge can be accessed from Chapter 4 in CSIRO and Bureau of Meteorology (2015) and associated reference material.

Projecting climate change

The climate is known to have changed over millennia through examination of air trapped in proxy records such as ice cores. Examination of layers in ice cores and other proxies has shown that the composition of the atmosphere has varied between glacial (ice ages) and inter-glacial (warm) periods and the average climate has changed around every 10,000-12,000 years. Further, the composition of CO_2 in the atmosphere has generally been around 200ppm during glacial periods and 280ppm during inter-glacial periods.

Factors that can cause climate change include:

- Changes in the Earth's orbit around the sun
- Changes in the sun that can affect the amount of solar radiation coming to the Earth
- Volcanic eruptions that can put large amounts of ash (aerosols) into the atmosphere which can decrease the amount of solar radiation reaching the Earth, resulting in cooler temperatures
- Changes in the concentrations of gases (such as CO_2) in the atmosphere.

In the 19th Century, Svante Arrhenius discovered the potential relationship between increased greenhouse gases in the atmosphere and temperature. A timeline of improved understanding of climate science including global and Australian responses to the science is reproduced in Figure 3.3.

Throughout the world a number of global climate models have been developed that aim to simulate the interactions of the world's atmosphere, oceans and land surface. These models are used for weather forecasting, to longer-term seasonal climate forecasts, to projecting climate change. The Coupled Model Intercomparison Project (CMIP) is a standard experimental protocol that commenced in 1995 for examining the outputs from these coupled atmosphere-ocean general circulation models (www.cmip-pcmdi.llnl.gov/). The latest series of models projecting future climate are referred to as the CMIP5 series.

The IPCC Fifth Assessment Report (2013) using the CMIP5, also defines the methodologies and temporal scales for how climate scientists measure the change in climate (e.g. temperature, rainfall, evaporation, humidity etc.). In this Plan historical climate is based on the average climate for a 20-year period (1986-2005) as the baseline, which is centred at 1995. Future climate scenarios from climate modelling for time periods also follow this definition 2030 (2020-2039), 2050 (2040-2059), 2070 (2060-2079).

Understanding of the **relationship between the earth's atmosphere and temperature**

Discovery that certain **gases block infra-red radiation** and prediction that changes in their concentration would lead to climate changes

Calculation that **human emissions of carbon dioxide (CO_2)** would lead to global warming.

Warming trend since late 1800s documented

Advances in **understanding of the global atmosphere**

Study of Man's Impact on Climate conference warns of rapid and serious climate change **caused by humans**. This conference dramatically increased awareness of climate change.

Scientists call for **international agreements** to reduce greenhouse gas emissions

Intergovernmental Panel on Climate Change (IPCC) established to provide **clear scientific information** about potential environmental, social and economic impacts of climate change.

First IPCC Report showing **earth already warmed**

Breaking up of Antarctic ice shelves

Second IPCC report, **confirming human "signature" on warming** and predicting serious future warming

Borehole data **confirm warming trend**

Third IPCC report, predicting s**evere impacts of unprecedented global warming**

Fourth IPCC report showing h**igh economic, social and environmental costs** of climate change impacts

Decline of Greenland and Antarctic ice sheets and Arctic ocean sea-ice

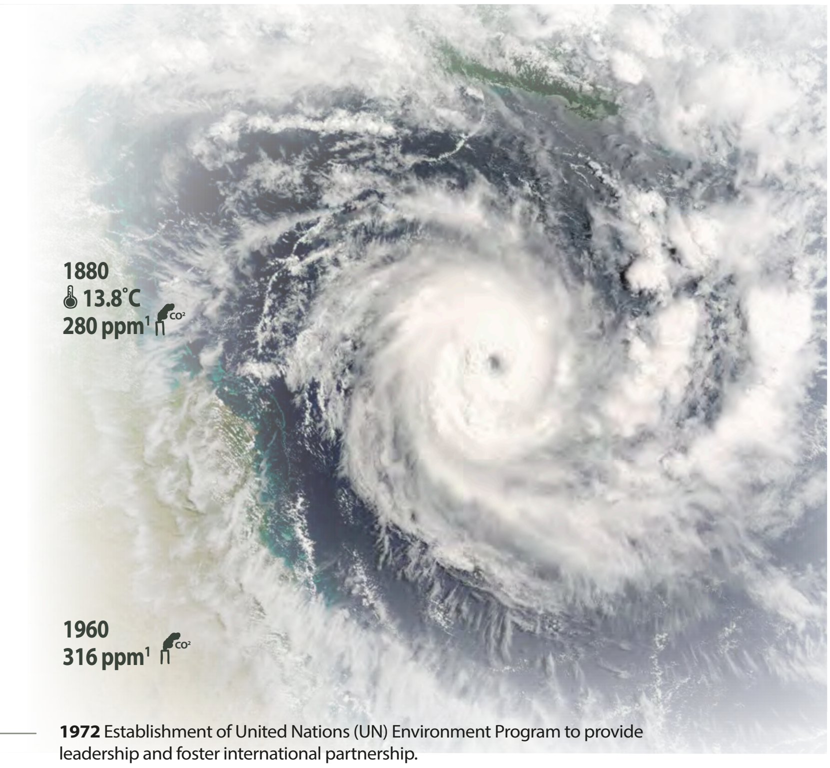
Bureau of Meteorology (BOM) adds two colours to extreme temperature mapping because of new **record high temperatures**

Fifth IPCC report, demonstrating **need for mitigation of greenhouse gas emissions** to avoid devastating climate change impacts

Australian BOM and CSIRO release climate report showing warming temperatures and **projecting continued warming, sea level rise and ocean acidification**

CSIRO and BOM publish downscaled climate projections for the Wet Tropics NRM cluster region

Year: 1820, 1830, 1840, 1850, 1860, 1870, 1880, 1890, 1900, 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2010, 2020



1972 Establishment of United Nations (UN) Environment Program to provide leadership and foster international partnership.

1978 US National Climate Program Act to co-ordinate climate programs and policies

1979 Scientific knowledge and concern building. World Climate Program launched within World Meteorological Organization to urgently improve understanding of global climate system.

1987 Montreal Protocol enables successful international action on reducing global emissions of ozone-damaging gases

1988 Scientific understanding being transformed into a policy issue. Toronto conference calls to reduce emissions of greenhouse gases by 20% by 2005. UK conservative Prime Minister Thatcher calls for action on climate change.

1992 Framework for Convention on Climate Change signed by 154 countries. A legally binding agreement on the need to stabilise levels of greenhouse gases.

1997 Kyoto protocol negotiated; 84 signatories.

1997 *Australia chooses not to ratify Kyoto protocol*
1997 *Australia establishes Australian Greenhouse Office*
1998 *Australian National Greenhouse Strategy*

2005 European Union Emissions Trading Scheme (ETS) commences. A market-based approach to controlling emissions of greenhouse gases which provides economic incentives to reduce emissions.

2007 *Australia ratifies Kyoto protocol*

2009 Copenhagen Conference achieves an agreement on a two degree guardrail and 30 billion dollars in commitments from developed countries.

2011 Canada withdraws from Kyoto Protocol.

2011 *Australia introduces carbon price*

2012 Doha Amendment adopted, starting the second commitment period of Kyoto protocol 2013-2020

2014 UN Climate Summit, New York.

2014 *Australia repeals carbon price legislation*
2015 *Australia introduces Emissions Reduction Fund*

2014
14.6˚C
398 ppm[1] CO2

Information Sources
http://www.aip.org/history/climate/timeline.htm; www.skepticalscience.com; Edison M Salas (unpublished, James Cook University); http://climate.nasa.gov/climate_resources/28/; ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt; http://www.noaanews.noaa.gov/stories2011/20111109_greenhousegasindex.html

1) Figures are global averages; source www.noaa.gov
Produced by the Wet Tropics Cluster Brokering Hub, November 2015

Figure 3.3 *Timeline of improved understanding of climate science including global and Australian responses*

How is the climate changing?

Mauna Loa Observatory in Hawaii has the longest records of direct measurements of CO_2 in the atmosphere, beginning in the late 1950s. Despite knowledge and scientific evidence of the impacts of increased atmospheric CO_2 this trend has continued unabated (Figure 3.4).

The latest series of IPCC reports (https://www.ipcc.ch/report/ar5) provides the most current information on the state of scientific knowledge about climate change. This information is supplemented through the work completed by CSIRO/ BOM for specific clusters as described in Chapter 1. Turton (2014) discusses the climate projections for key climate variables in Chapter 2 of Hilbert et al. (2014) and is complemented by the Wet Tropics Cluster report (McInnes et al. 2015). Links to these documents can be found on the climate change pages of the Reef Catchments website (www.reefcatchments.com.au)

The IPCC AR5 developed four emissions scenarios entitled Representative Concentration Pathways (RCPs) that describe plausible trajectories of future greenhouse gas and aerosol concentrations to 2100 (Turton 2014), which are RCP2.6, RCP4.5, RCP6 and RCP8.5. In brief, RCP2.6 presumes that action has been taken to reduce emissions, RCP4.5 presumes that emissions are starting to reduce now and CO2 concentrations in the atmosphere have stabilised by 2040. RCP8.5 is the worst case or business as usual where there is no effort to reduce emissions. For further information about RCP's see Turton (2014) or Chapter 3 in CSIRO and Bureau of Meteorology (2015).

Projections in changes to the climate are linked with confidence statements due to the inability to predict the future. CSIRO and Bureau of Meteorology (2015) group the levels of uncertainty into three main categories:

- Uncertainty in scenarios due to not knowing future emissions and concentrations of greenhouse gases and aerosols
- Uncertainty in the response of the climate system which is a result of limitations in understanding of the climate system and its representation in climate models
- The uncertainty around the natural variability in the climate system and its response to climatic change.

Statements about future climate are therefore linked with confidence statements that range from very high confidence (almost certain) to low confidence.

Climate Projections for the MWI NRM region

There is compelling evidence that the global (and national) climate has changed and will continue to do so. Projected climate change level of confidence for the Macky Whitsunday Isaac NRM region including the relevant are as follows:

- Substantial increase in average, maximum and minimum temperatures *Very high confidence.*
- Substantial increases in the temperature of hot days, as well as in the frequency and duration of extreme temperatures *Very high confidence.*
- Average sea level and height of extreme sea-level events will continue to rise *Very high confidence.*
- Increases in evapotranspiration in all seasons *High confidence.*
- Increased intensity of extreme rainfall events *High confidence.*
- Less frequent but more intense tropical cyclones *Medium confidence.*
- Changes to rainfall are possible but unclear due to uncertainty in projecting change in some drivers of tropical rainfall *Low confidence.*
- Little change to fire frequency is projected; however where fires do occur fire behaviour will be more extreme *High confidence.*
- Higher sea levels and more frequent sea level extremes *Very high confidence.*
- Warmer and more acidic oceans in the future *Very high confidence.*

(Source: McInnes et al. 2015):

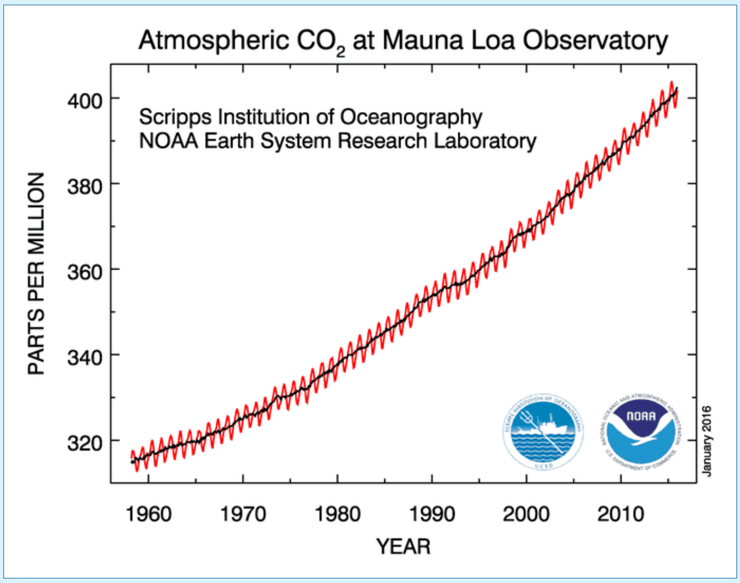


Figure 3.4 *Change in atmospheric concentration of CO^2 measured at Mauna Loa Observatory in Hawaii. (Source: www.esrl.noaa.gov/gmd/ccgg/trends. Accessed 18/1/2016)*

Methodology to determine future climate

CSIRO and Bureau of Meteorology (2015) developed a Climate Futures tool (www.climatechangeinaustralia.gov.au) for users to develop scenarios about change in climate variables for different seasons and timescales that could be applied to assess likely change from historical baseline climate at a regional level (based on the 20-year climatology of 1986-2005). Regional stakeholder groups were consulted on climate variables, seasons and timeframes for their areas of interest to conduct these analyses.

The climate variables analysed were temperature, rainfall, relative humidity and evapotranspiration. Seasons and timeframes are for 2030, 2050 and 2070 for four seasons (requested by the sugar industry), two seasons and annually. Although analysis of change to evaporation was requested, these analyses are only possible using CMIP3 models (IPCC's Coupled Model Inter-comparison Project used for the 2007 IPCC climate projections) and not the most recent suite of climate models (CMIP5) and were therefore not conducted. Further, historical records of evaporation, along with other climate variables such as wind-speed and humidity (for a 20-year climatology), are not available from the regional meteorological offices. Meteorological records were accessed from the Bureau of Meteorology website (www.bom.gov.au/climate/data/) for Mackay and Proserpine and the historical climate calculated for requested seasons. There is no meteorological station at Eungella therefore interpolated datasets on historical climate were generated from the Queensland governments SILO climate data drill (https://www.longpaddock.qld.gov.au/silo/).

The Climate Futures tool has the ability to generate climate projections based on emission scenarios (RCP's) using 42 global climate models. Two emission scenarios were used in these analyses: RCP4.5 which is described as greenhouse gases (or CO2 concentrations) stabilising in the atmosphere by 2040, and RCP8.5 business as usual or worst case scenario; which is also the current trajectory for global greenhouse gas emissions.

Due to the uncertainties in projecting future climate, three scenarios are also usually generated which are: best case (least change in the climate), worst case (greatest possible change in the climate) and maximum consensus (where most of the climate models agree on projected change). Consideration of the three scenarios in this way enables a range in the change trajectory to be generated for a specific climate variable. It was agreed by regional stakeholders to generate only the maximum consensus on likely climatic change; therefore the potential change is only given as an average figure and not the potential range. McInnes et al. 2015 presents the range generated through climate models for the Wet Tropics cluster for 2030 and 2090.

The Climate Futures tool generates scenarios from cluster regions (in this case Wet Tropics Cluster) and the user selects the case (maximum consensus) to generate a model that can then be applied to the historical climatology. These scenarios are also linked with confidence limits. The detail around the results from the Climate Futures Tool and climate models that generated the results are appended (Appendix 1).

Climate Futures for the MWI NRM region

The locations of the region's meteorological offices (Mackay and Proserpine airport) are shown in Figure 3.5. Eungella has a distinctively different climate to both Mackay and Proserpine due to its higher elevation and topography and is also depicted on the map.

The 20-year climatology (1986-2005) for the wet (November to April) and dry (May-October) determined from BOM records (Mackay and Proserpine) and Eungella (SILO) are shown in Table 3.1.

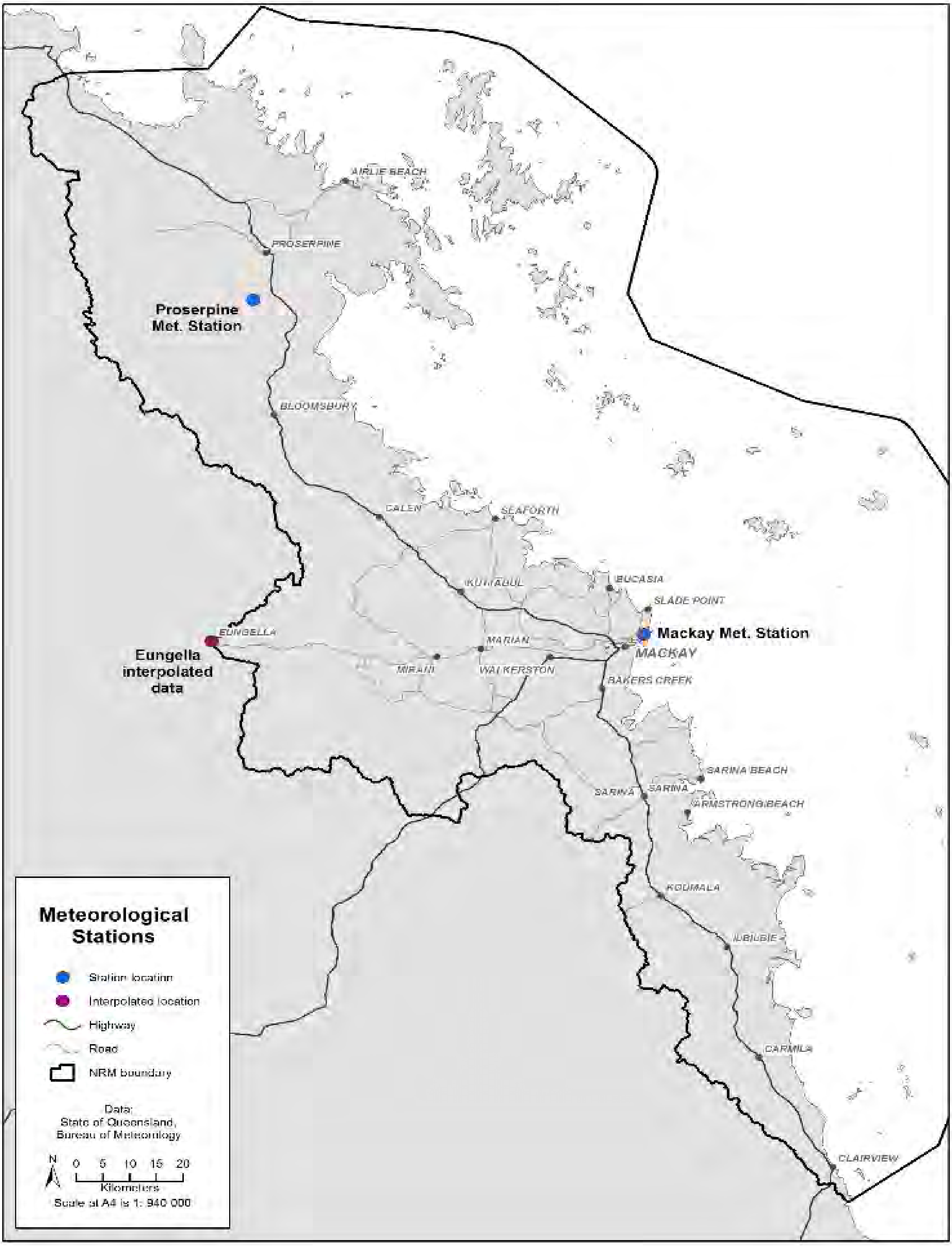


Figure 3.5 *Location of areas in the region examined for future climate*

Table 3.1 *20-year climatology for Mackay, Eungella and Proserpine*

Site	Temperature (°C)				Rainfall (mm)		
	Wet Season		Dry Season				
	Maximum	Minimum	Maximum	Minimum			
					Wet Season	Dry Season	Annual
Eungella	29.4	19.5	24.0	12.7	1085	372	1457
Proserpine	30.9	21.9	26.6	14.3	1216	238	1454
Mackay	29.3	22.5	24.0	16.1	1179	313	1492

Note: Additional information relating to seasonal historical climatology for four seasons and other climate variables derived from SILO are appended (Appendix 1).

As described earlier in this chapter there is significant variability from year to year in large-scale climate drivers and the variation in topography across the region.

Results from the Climate Futures tool, model consensus and projected change are shown in Table 2.2 for a range of climate variables.

Table 3.2 *Projected seasonal change in climate (for the maximum consensus case) for a range of climate variables for NRM regions in the Wet Tropics cluster (expressed as °C change for temperature and percentages for rainfall, humidity and evapotranspiration)*

	2030		2050		2070		2090	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Model Consensus	Moderate	High	Moderate	Moderate	Moderate	Moderate	Low	Low
Climate Variable								
Temperature								
Max (wet)	0.6	0.7	1	1.2	0.9	2.2	1.3	2.2
Min (wet)	0.6	0.6	1	1.2	0.6	2.2	1.2	2.1
Max (dry)	0.7	0.6	1	1.2	0.9	2.1	1.3	2.4
Min (dry)	0.7	0.6	1	1.3	0.7	2.2	1.3	2.3
Rainfall								
Wet	6	-5	6	1	1	12	-1	-5
Dry	-2	-6	-4	5	2	10	-3	-1
Humidity								
Wet	0	0	0	0	1	0	0	1
Dry	1	0	-1	1	1	0	-1	3
Solar radiation								
Wet	0	1	-1	1	0	-2	0	-1
Dry	0	1	0	0	0	-2	-1	-1
Evapotranspiration								
Wet	2	3	2	5	3	5	3	7
Dry	3	3	4	5	3	7	4	10

Note: RCP 4.5 Emissions stabilising in the atmosphere by 2040, RCP 8.5 business as usual and no curbing of Emissions.

Certainty around the climate futures varies with only moderate consensus amongst models for most of the futures analysed. It needs to be kept in mind that these results need to be interpreted with the general statements previously as to confidence around change in climate variables.

Ongoing increases in temperature appear relatively small; however increasing average temperatures for all seasons and more extreme weather events (e.g. heatwave events as the average temperature baseline increases) will have a range of impacts on sustainability for the MWI region. This is discussed in more detail in later chapters. **There is low confidence around the direction of rainfall change for the Wet Tropics cluster region and these results need to be used with caution.** Changes in humidity and solar radiation appear negligible but may have an impact on ecosystem health in concert with increasing temperatures. Changes in evapotranspiration are positive for all seasons with greater changes toward the end of the century. It is evident though that projected change, at various temporal scales, is greatest under the higher emissions scenario (RCP8.5).

The following bar graphs depict projected changes in temperature to 2070 (2090 excluded due to low model consensus) for two seasons (wet and dry), relative to the historical climatology for Eungella (Figure 3.6), Proserpine (Figure 3.7) and Mackay (Figure 3.8).

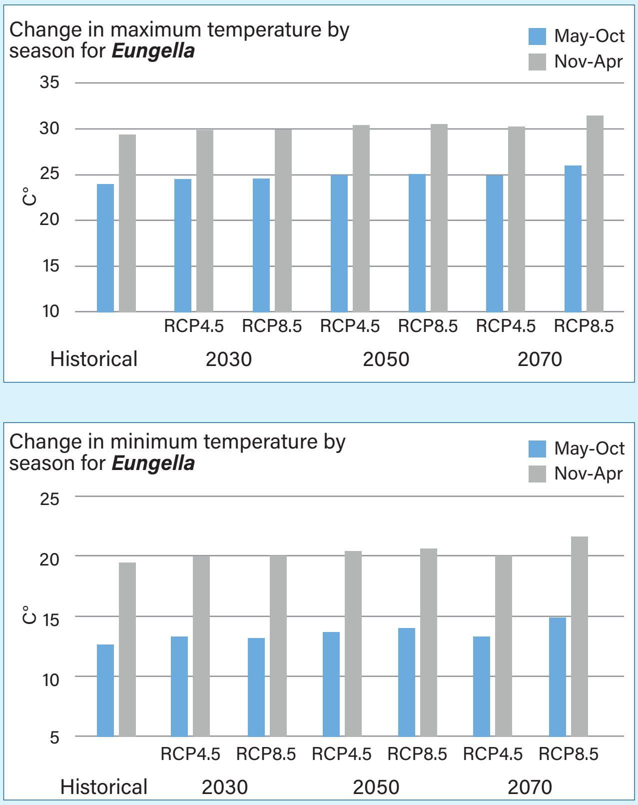


Figure 3.6 *Projected change in maximum and minimum temperature for two seasons (wet and dry) for Eungella (maximum consensus case) for RCP4.5 and RCP8.5*

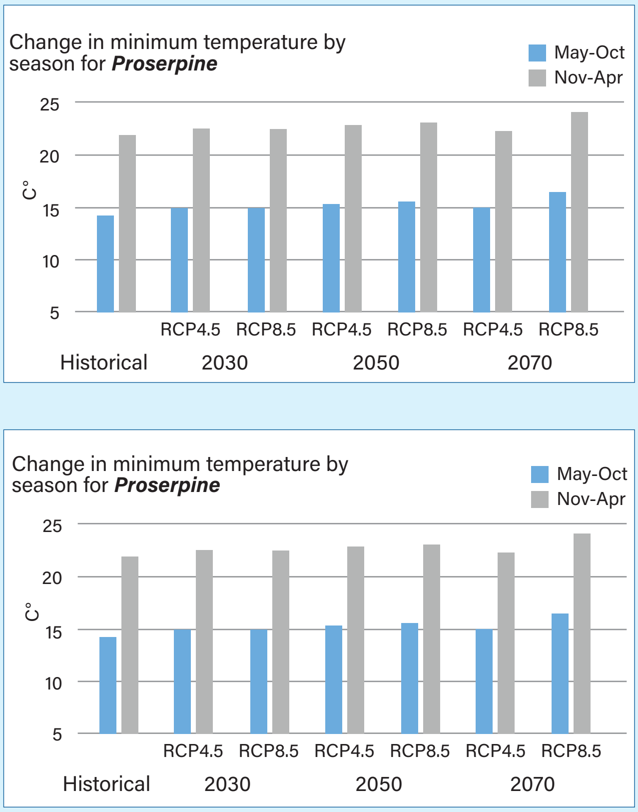


Figure 3.7 *Projected change in maximum and minimum temperature for two seasons (wet and dry) for Proserpine (maximum consensus case) for RCP4.5 and RCP8.5*

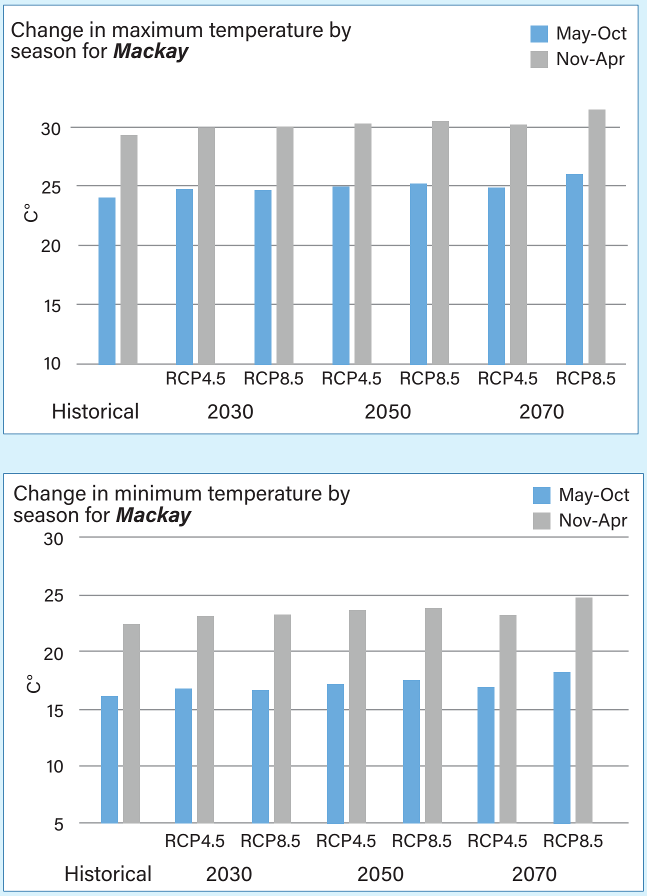


Figure 3.8 *Projected change in maximum and minimum temperature for two seasons (wet and dry) for Mackay (maximum consensus case) for RCP4.5 and RCP8.5*

Projected changes appear small; however projections around extreme events by climate scientists into the future provide a very high confidence for extreme temperature (hot days are getting hotter) and high confidence for intense rainfall events. Temperature and rainfall extreme events impact highly on all aspect of sustainability due to damage to infrastructure, social and cultural health and wellbeing as well as natural ecosystems. Increased frequency of these events reduces the ability to recover: most particularly in natural ecosystems.

Figure 3.9 shows the projected changes to extreme temperature (a) and rainfall (b) for the Wet Tropics cluster for RCP 2.6, 4.5 and 8.5. RCP 2.6 has not been used in previous content as this presumes global emissions have already started to decline. For both graphs the middle bold line is the median value of the model simulations (20 year moving average). The dark shaded areas show the range (10th to 90th percentile) of model simulations of 20-year average climate. The light shaded areas represent the projected range (10th to 90th percentile) of individual years taking into account year to year variability in addition to the long-term response.

Figure 3.9a demonstrates that agreement amongst the models is higher for extreme temperature events with a distinctive upward trajectory that increases with increased greenhouse gas emissions.

There is a high level of variability in rainfall extremes (Figure 3.9b); however the majority of models show an upward trajectory for increased intensity of rainfall events under higher emissions (RCP8.5).

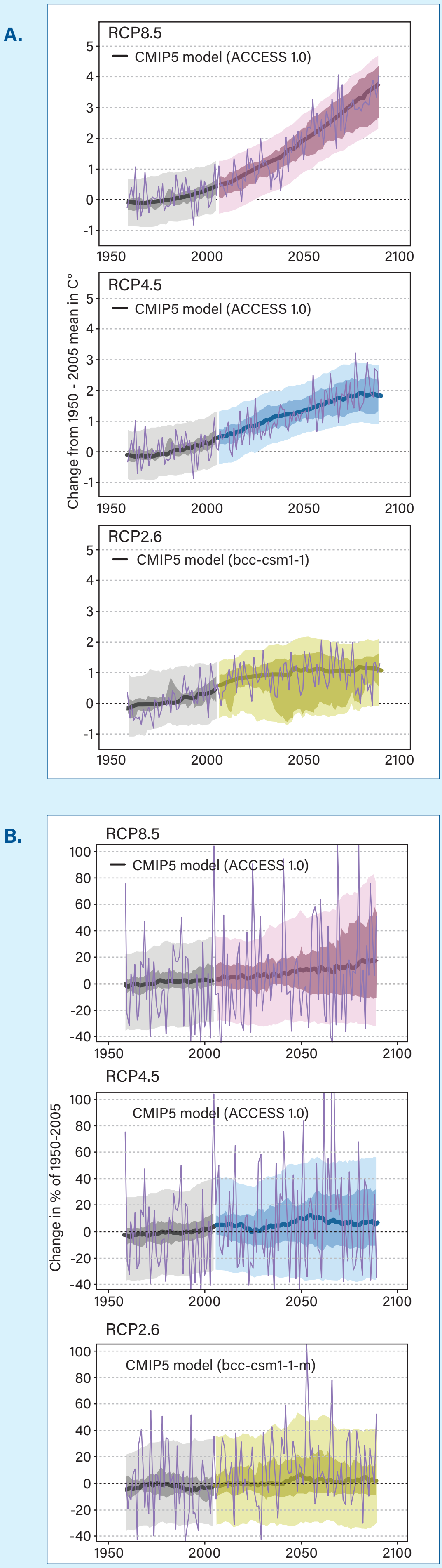


Figure 3.9 *Projected change in maximum temperatures (a) and rainfall extremes (b) for RCP 2.6, 4.5and 8.5.*

CSIRO and Bureau of Meteorology (2015) as a part of their online portal have developed spatial tools for examination of potential climate futures for the region including how extremes may change into the future (see http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/). This tool was used to examine how extreme temperatures (number of days greater than 35°C) may change around Mackay and Proserpine. These results are shown in Figure 2.10

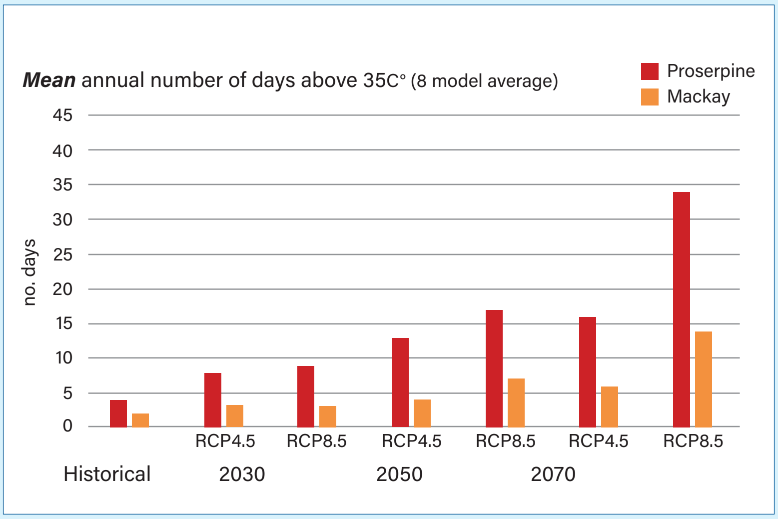


Figure 3.10 *Mean annual number of days to exceed 35°C (based on the 20-year historical climatology) and into the future in Mackay and Proserpine.*

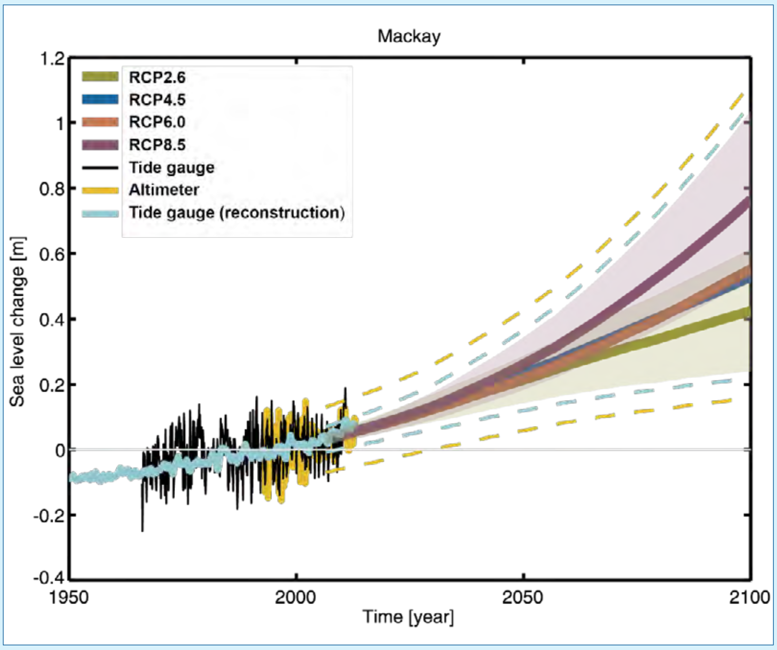


Figure 3.11 *Observed and projected relative sea level change (m) for Mackay. The observed tide gauge relative sea level records are indicated in black, with the satellite record (since 1993) in mustard and tide gauge reconstruction in cyan. Multi-model mean projections (thick purple and olive lines) for the RCP8.5 and RCP2.6 emissions scenario with uncertainty ranges shown by the purple and olive shaded regions from 2006 to 2100. The mustard and cyan dashed lines are an estimate of inter-annual variability in sea level (uncertainty around the projections), and indicate that individual monthly averages of sea level can be above or below longer-term averages. Note if a collapse in the marine based sectors of the Antarctic ice sheet were initiated, these projections could be several tenths of a metre higher by late in the century (Source McInnes et al. 2015)*

Climate Futures for the MWI NRM region (cont.)

Extreme heat events cause problems with infrastructure failing, mortality in fauna, flora and human health impacts. Extreme heat events occur more often currently around Proserpine than Mackay; however are likely to double by 2030, regardless of the emissions trajectory. It again is clear that aiming towards a lower emissions trajectory can reduce these impacts into the future.

Coastal and marine impacts

Changes in mean sea levels and extremes (e.g. storm surges), sea surface temperatures (SSTs) and ocean acidity have potential to affect the coastal zone (ecosystems and coastal communities) and marine environments which are projected to increase with very high confidence (McInnes et al. 2015). Ocean thermal expansion and melting of glaciers and ice caps are the main contributors to global sea level change (CSIRO and Bureau of Meteorology 2015). Mean sea levels are also impacted in Australia by large-scale climate drivers (e.g. during El Niño events mean sea level is lower and La Niña mean sea level is higher). Sea level rise around Australia was 1.4 mm per year between 1966 and 2009 and 1.6 mm per year when the influence of ENSO on sea level was removed (McInnes et al. 2015); however the rates of sea level rise are not uniform around the continent.

SSTs have already increased significantly across the globe in recent decades. In Australia, SST's have also increased; however these increases are also influenced by the currents along the east and west coasts of Australia (e.g. Eastern Australian current and Leeuwin Current) which have intensified, taking warmer waters further south of the continent (CSIRO& Bureau of Meteorology, 2015). For the cluster region, the projected ongoing rise is generally greatest in the south (Mackay Whitsunday) and smallest in the Gulf of Carpentaria (McInnes et al. 2015).

About 30% of anthropogenic (human-induced) CO2 emitted into the atmosphere over the past 200 years has been absorbed by the oceans and has ultimately led to a 26% increase in acidity globally (McInnes et al. 2015). Increasing ocean acidification impacts on marine ecosystems and fisheries, reduces the ability of marine organisms to form hard skeletons (such as coral) or shells (such as prawns and oysters) and can also lower the temperature at which corals bleach.

Mackay has a continuous tide gauge record for the period 1966-2010 and projected relative sea level change is shown in Figure 3.11.

The Wet Tropics cluster report (McInnes et al. 2015) provides projections on change in marine climate variables for a range of sites around the Wet Tropics cluster region for 2030 and 2090. It is important to note that the range in sea level rise projections may be several tenths of a metre higher late in the century if a collapse in the marine based sectors of the Antarctic ice sheet were initiated. The projections for Mackay for two RCP's (4.5 and 8.5) are reproduced in Table 3.3 below.

Table 3.3 *Projected change in marine climate variables for Mackay (Latitude 149.23° E, Longitude -21.1° S)*

	2030		2090	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Variable				
Sea level rise (m)	0.13 (0.09 to 0.17)	0.14 (0.09 to 0.18)	0.47 (0.3 to 0.64)	0.64 (0.44 to 0.87)
*Sea allowance (m)	0.14	0.14	0.53	0.73
Sea Surface Temperature (° C)	0.7 (0.5 to 0.9)	0.8 (0.5 to 1.0)	1.5 (1.5 to 1.8)	2.9 (2.2 to 3.4)
Ocean acidification	-0.07 (-0.07 to -0.06)	-0.08 (-0.08 to -0.07)	-0.15 (-0.15 to -0.14)	-0.32 (-0.32 to -0.31)

*Minimum distance required raising an asset to maintain current frequency of breaches under projected sea level rise (see McInnes et al. 2015 for further detail).

SUMMARY

- The MWI region has high natural climate variability which is higher than other parts of Australia and is known globally as having the highest natural climate variability in the world
- Temperature increases will continue in all seasons, however these can be masked by large-scale drivers of natural climate variability such as ENSO
- The direction of rainfall change is not clear but can be expected to be more variable in the future
- Evapotranspiration will increase in all seasons
- Extreme weather events will increase (temperature and rainfall)
- Sea level rise and extreme sea events (e.g. storm surges) will increase and have impact further inland.

CHAPTER 4

Climate vulnerability in the MWI NRM Landscape

The region's biodiversity has been dramatically impacted by extensive clearing and fragmentation of vegetation and continues to decline as a result of this and other pressures; these are articulated in the State of Region (SORR) report (Reef Catchments, 2013b). As a result, the capacity of the region's natural systems to respond to disturbance or change by withstanding damage or recovering rapidly (i.e., their resilience) is already reduced. The scale and rate of current climate change would be too large for some components of natural systems to withstand or recover from (Hilbert et al. 2014). The additional pressures associated with human land uses further reduce the ability of natural systems to adapt to a changing climate.

There is also substantial economic and social climate vulnerability in the region. Extreme weather events such as storms and floods already have a significant impact on communities, industries and the economy. For example, the cost of rebuilding public infrastructure and supporting businesses and the community from the 2010-11 Queensland floods and Cyclone Yasi totalled approximately $6.8 billion for Queensland (Queensland Treasury, 2011). In the February 2008 floods in Mackay, 4000 houses were inundated with floodwater while agriculture and horticulture based industries also sustained heavy damage. The estimated damage was $410 million (https://www.emknowledge.gov.au/resource/494/2008/flood---mackay-queensland-2008). Existing landscape risk (or hazards) have been identified by the Queensland government for use in Local and State government land use planning and decision-making.

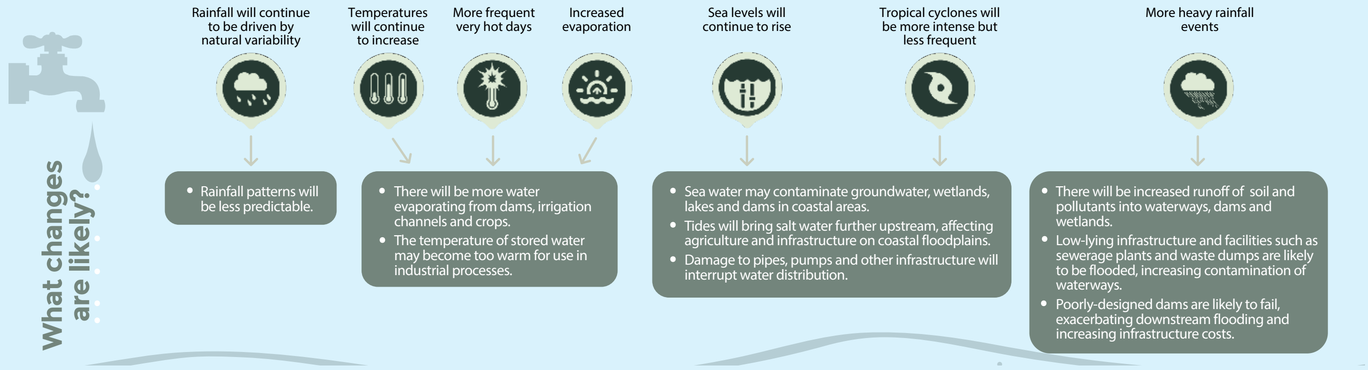
Spatial data sources are provided in Appendix 2. Spatial information provided in this chapter is supplemented at local scales for the Sarina, Mackay and the Whitsundays Landcare regions in a supporting document to this Plan (Supplementary spatial data for Sarina, Mackay and the Whitsundays).

Projections for more frequent and heavier rainfall during extreme rainfall events, and for more intense cyclones in the region will increase vulnerability in terms of the extent (area) and intensity (damage) of impacts. Other projected climate changes, including increasing temperatures, sea level rise and less predictable rainfall will also have far-reaching impacts for the region.

The information in this chapter is intended to help identify some of the main risks associated with the projected climatic changes described in Chapter 3 and have been grouped into five themes:

- Freshwater
- Sustainable industries
- Healthy communities
- Plants, animals and habitats
- Invasive species

Most of this information is based on a recent synthesis of scientific information about the risks of climate change in north-eastern Australia (Hilbert et al., 2014) and summarised in a series of fact sheets produced by the Wet Tropics Cluster Brokering Hub (2015). Regional stakeholders have also provided input on what current and projected climatic changes may mean for sustainability in the region. Other sources of information are identified in the text. This information sets out the likely risks for the MWI region; the actual areas that face increased risk will generally depend on the emissions trajectory, the nature of government policy to support adaptation and the time frame considered.



Freshwater availability

Rainfall patterns in the region will be less predictable. The demand for freshwater will increase with an increasing population and evaporative losses from crops, but at the same time, the availability of freshwater will decline due to increasing evaporation, sea level rise, seawater intrusion into freshwater coastal aquifers and contamination during flood events. Reduced supply of freshwater is recognised as a major impact of climate change throughout the world.

Changed rainfall

There is a large amount of uncertainty around changes in patterns of average rainfall in the region, scientists are not confident whether annual rainfall will increase or decrease, nor how seasonal patterns are likely to change. However it is very likely that rainfall will be less predictable and that seasonal changes will be especially marked (CSIRO & BOM, 2015).

While it is presently difficult to anticipate the specific impacts of climate change on the availability of freshwater from rainfall, land-use planning and management practices based on past experiences of rainfall patterns will become less reliable or appropriate. Keeping track of actual changes in rainfall over time, and how this is influenced by large-scale climate drivers will help determine whether and how to adjust patterns of water storage and use.

Increased temperature, hot spells and evaporation

More water is likely to be lost from dams, irrigation channels and crops as a result of these changes. It is therefore likely that less freshwater will be available, unless rainfall increases. This has implications for town and rural domestic water supplies, through the reduced availability of water for extraction from rivers and streams and less water for aquatic ecology and fish migration. This is also potentially compounded by increased tidal reach and sea-water intrusion into coastal aquifers as a consequence of sea level rise and subsequent loss from storage reservoirs. In brief, it is likely that there will be less freshwater available for municipal and rural water supplies as demand increases with the growing population (Reef Catchments, 2014a).

The supply of water for use in farming and other industries will be similarly affected. Increased evaporation of moisture from crops and pastures will also lead to an increased need for water inputs, but within the likely context of reduced availability. Furthermore, increased temperatures, particularly during hot spells, will heat stored water, potentially to temperatures above levels suitable for industrial cooling, for example, as is used in some industrial processes such as sugar milling in the region. This would lead to more frequent shut-down of industrial operations, with consequences through the supply chain.

Higher sea levels and intense tropical cyclones

Sea level rise will have the greatest impacts in coastal areas, where wetlands, lakes and dams are likely to be flooded more often by rising ocean waters. In some low-lying areas, inundation will be permanent, while other areas that are situated just above current high tide levels will become exposed to tidal inundation. Areas that are currently exposed to storm surge and those that will be affected by storm surge with projected sea level rise (0.8m by 2100) are shown in Figure 4.1. Note that a rise of 0.8m in average sea level is now considered to be a conservative projection.

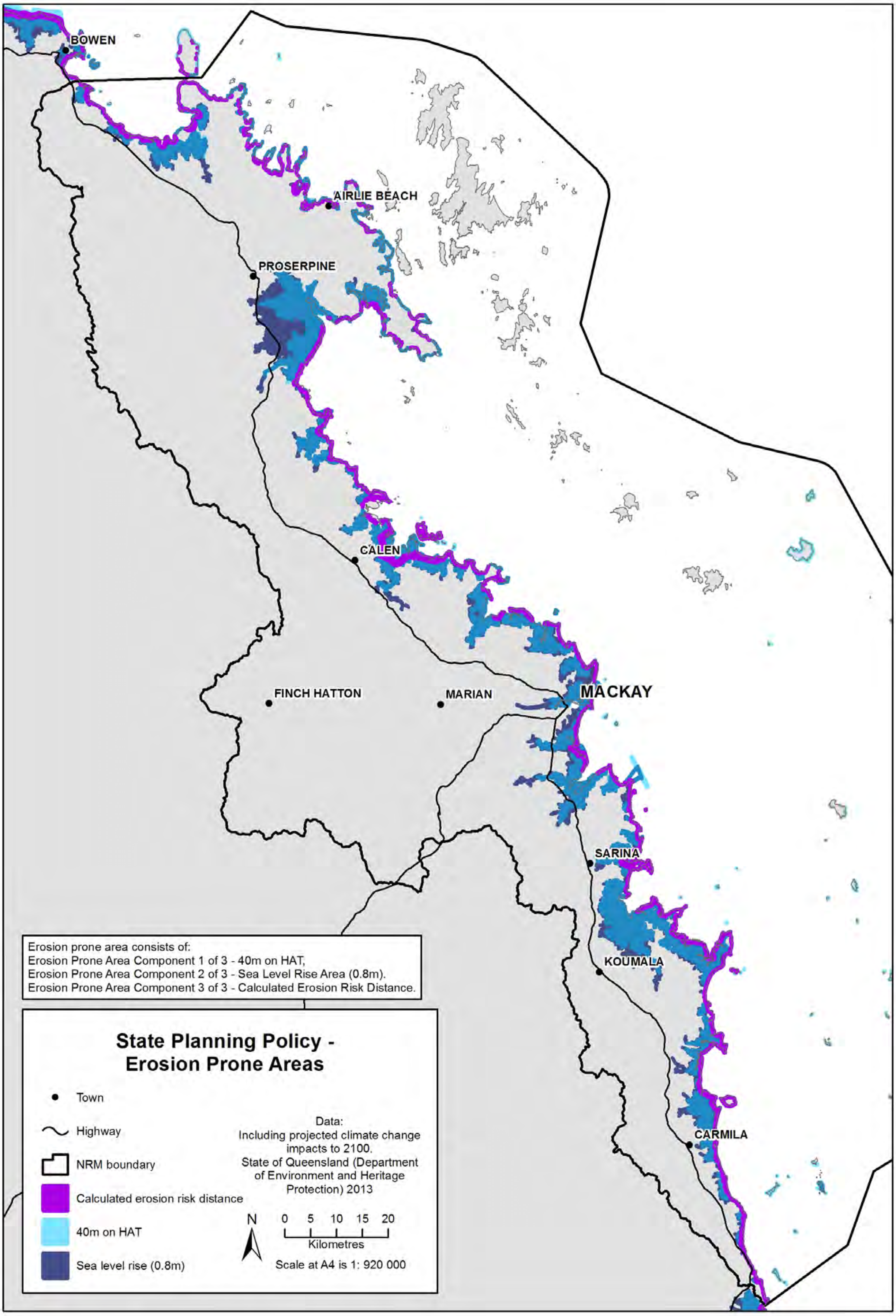


Figure 4.1 *Areas projected to be affected by storm surge with sea level rise of 0.8 m by 2100.*

The extent of tidal inundation into these areas will be exacerbated in the short term by more intense cyclones and storms which will increase erosion of sand dunes and damage mangroves and other natural barriers which separate ocean and freshwater habitats. Low-lying ponded pasture in the MWI region faces substantial risk from sea level rise. Furthermore, intense cyclones generate larger storm tides, which increase the risk of inundation in many coastal areas of the MWI region. The MWI NRM Plan (Reef Catchments, 2014a) identifies that storm tides are already a high hazard for settlements such as Airlie Beach, Cannonvale, all coastal settlements and several islands. The Goorganga Plains and Gregory River estuary, the salt pans of Blackrock and Murray Creeks are also identified as high risk for storm tide inundation. Mackay CBD is considered to be currently at medium risk of inundation on storm tides (Reef Catchments, 2014a).

Freshwater supply in coastal areas is also at risk from seawater intrusion into groundwater as a result of the shifting balance of fresh and saltwater in coastal groundwater aquifers (Figure 4.2, below). These processes of seawater intrusion into coastal groundwater will result in the salination of bore water, reducing availability of freshwater in these areas. Seawater intrusion into groundwater risks being compounded if there is increased extraction from groundwater (see above about increasing demand for water in agriculture with increased evaporation) and prolonged dry periods. Extraction will need to be monitored and managed appropriately to respond to these changes.

The Queensland Department of Natural Resources and Mines (QDNRM) manages and monitors an extensive network of groundwater bores throughout the region (Figure 4.3). Seawater intrusion was recognised as an issue for management in the Pioneer Valley Water Resource Operations Plan (Queensland Government 2002) and includes a seawater intrusion baseline for the Pioneer Valley. QDNRM monitors and manages bores to track water quality (including electrical conductivity (EC)) to maintain water supply and quality in the region. This includes managing usage to minimise further intrusion of seawater into coastal aquifers. The EC of seawater is 54,000 µS/cm. Reef Catchments analysed the DNRM groundwater monitoring database for bores with EC greater than 40,000 µS/cm and few bores were found in the region exceeding this threshold (Figure 4.3). EC can vary significantly in bore water dependent on recharge (e.g. high rainfall events), lack of recharge or the underlying geology of the substrate. For example, large areas of the Goorganga Plains are derived from marine sediments therefore would have naturally high levels of salinity (or EC). Long-term monitoring and planning is essential to manage the groundwater resource and where possible minimise seawater intrusion. Nevertheless, extensive areas of the MWI coastal plain currently under sugar cane may potentially be impacted by the salination of groundwater in the future. Ongoing monitoring of this extensive network of bores is essential to ensure seawater intrusion is minimised; where possible, into freshwater coastal aquifers.

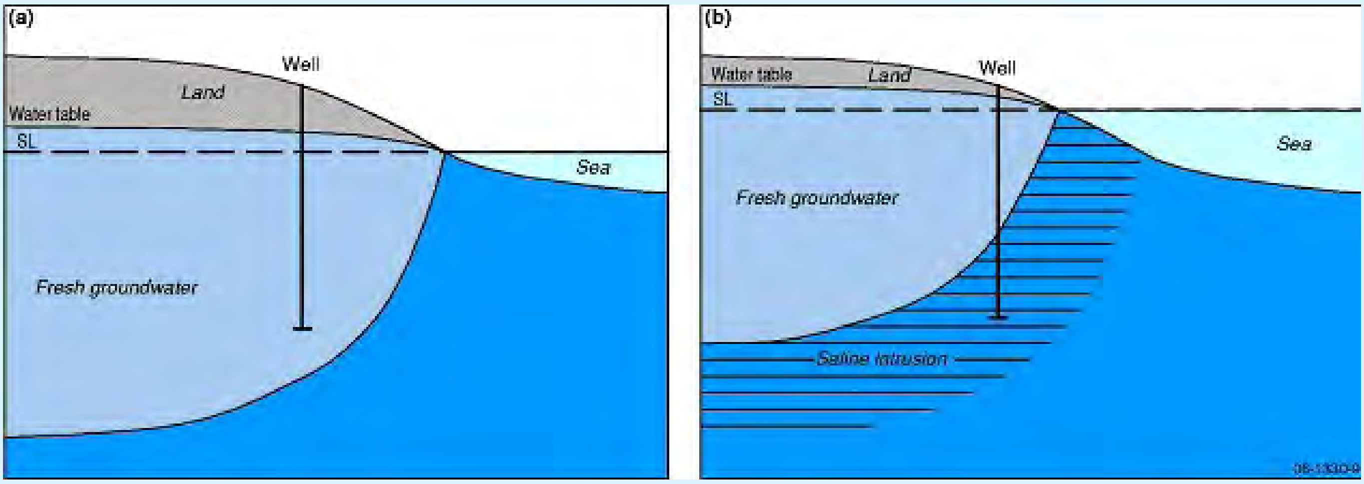


Figure 4.2 *Depicts saline intrusion as a result of sea level rise, showing (a) a hypothetical coastal aquifer under current conditions and (b) the same aquifer under a scenario of higher sea level. The consequences for groundwater extraction are shown for a hypothetical well/bore. (Source* http://www.ozcoasts.gov.au/indicators/saline_intrusion.jsp)

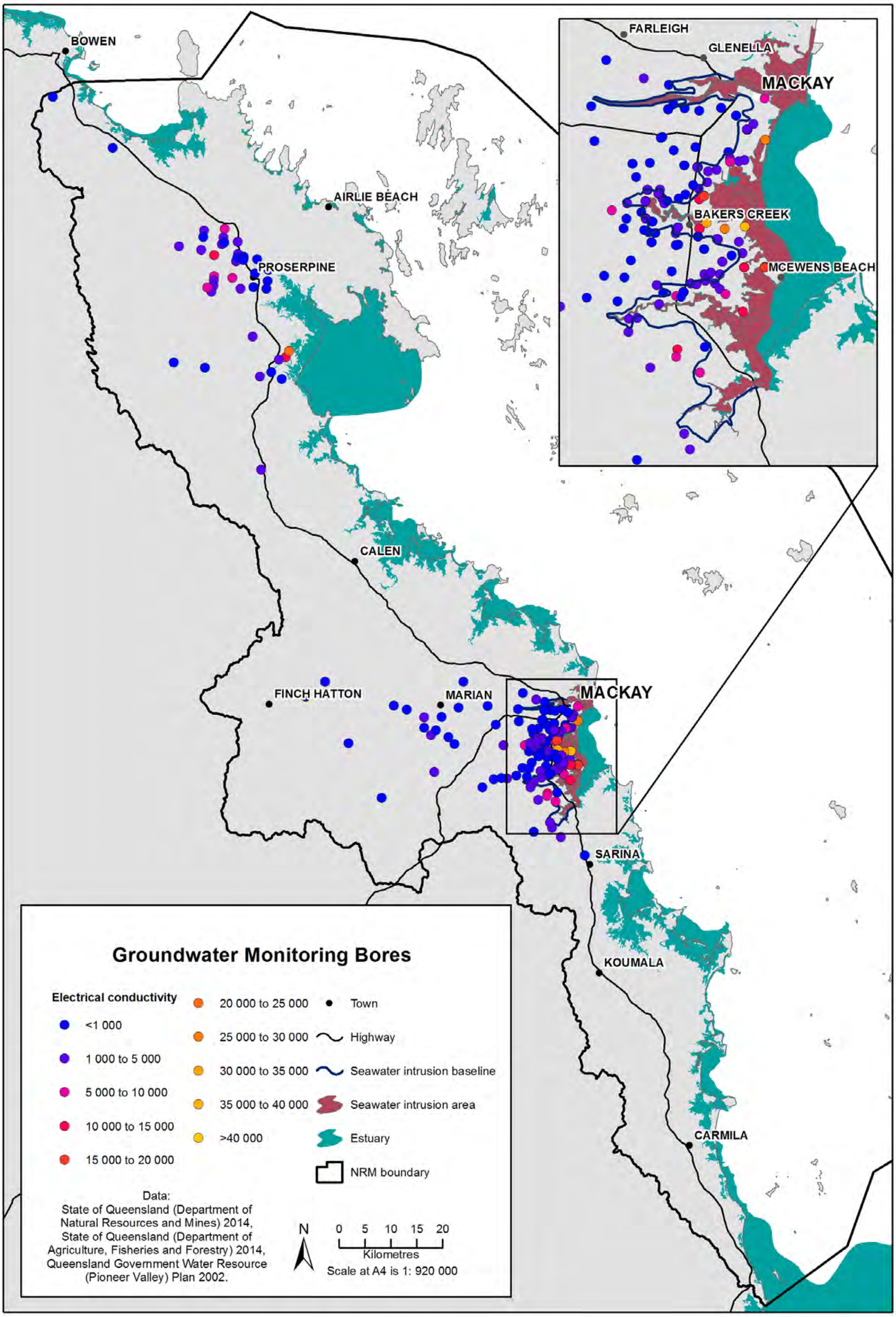


Figure 4.3 *Location of long-term groundwater monitoring bores (and most recent EC reading) and existing estuarine areas in the MWI NRM region.*

Higher sea levels also bring the risk of increased tidal penetration, that is, the movement of seawater further upstream than is currently the case. Increased tidal penetration will reduce the availability of freshwater for extraction from waterways and directly affect agriculture on surrounding land, for example through high tide inundation or during flood events that coincide with storm tides. Increased tidal penetration risks increasing corrosion rates of pumps, pipes and other water distribution infrastructure. The existing reach of estuarine areas is also shown in Figure 4.3.

Cyclones also impact freshwater availability by causing damage to water distribution infrastructure and interrupting power supplies. As more intense cyclones are projected to occur in the future, the areas affected and economic cost of shut-down and repair are likely to increase.

Extreme rainfall

Many areas of the MWI region are already vulnerable to flooding. Projections show that flooding from extreme rainfall events will be more frequent and will affect more extensive areas of the region. The existing flood risk mapped by the Queensland Government is shown in Figure 4.4.

In terms of the consequences for impacts on fresh water availability, flooding may lead to contamination of fresh water supplies, either through increased runoff of soil and pollutants into waterways and dams or as a result of inundation of low-lying water treatment, sewerage and other waste facilities. More frequent and widespread contamination of water will impact towns, agricultural and industrial supplies, as well as the longer-term health of freshwater systems. More frequent or serious damage to these facilities will disrupt service provision and increase maintenance costs.

With more intense heavy rainfall events, farm and municipal dams are more likely to fail, exacerbating downstream flooding, but also reducing water storage capacity after the event, and increasing the economic costs associated with supplying water. Similarly, pumps, pipes and other water distribution infrastructure are at risk of more frequent damage.

The conventions of a 1 in 20 or 1 in 100 year flood event have already shifted due to the changing climate. In a warming world a 1 in 20 year flood event may become a 1 in 10 or 1 in 5 year event depending on emissions trajectories into the future.

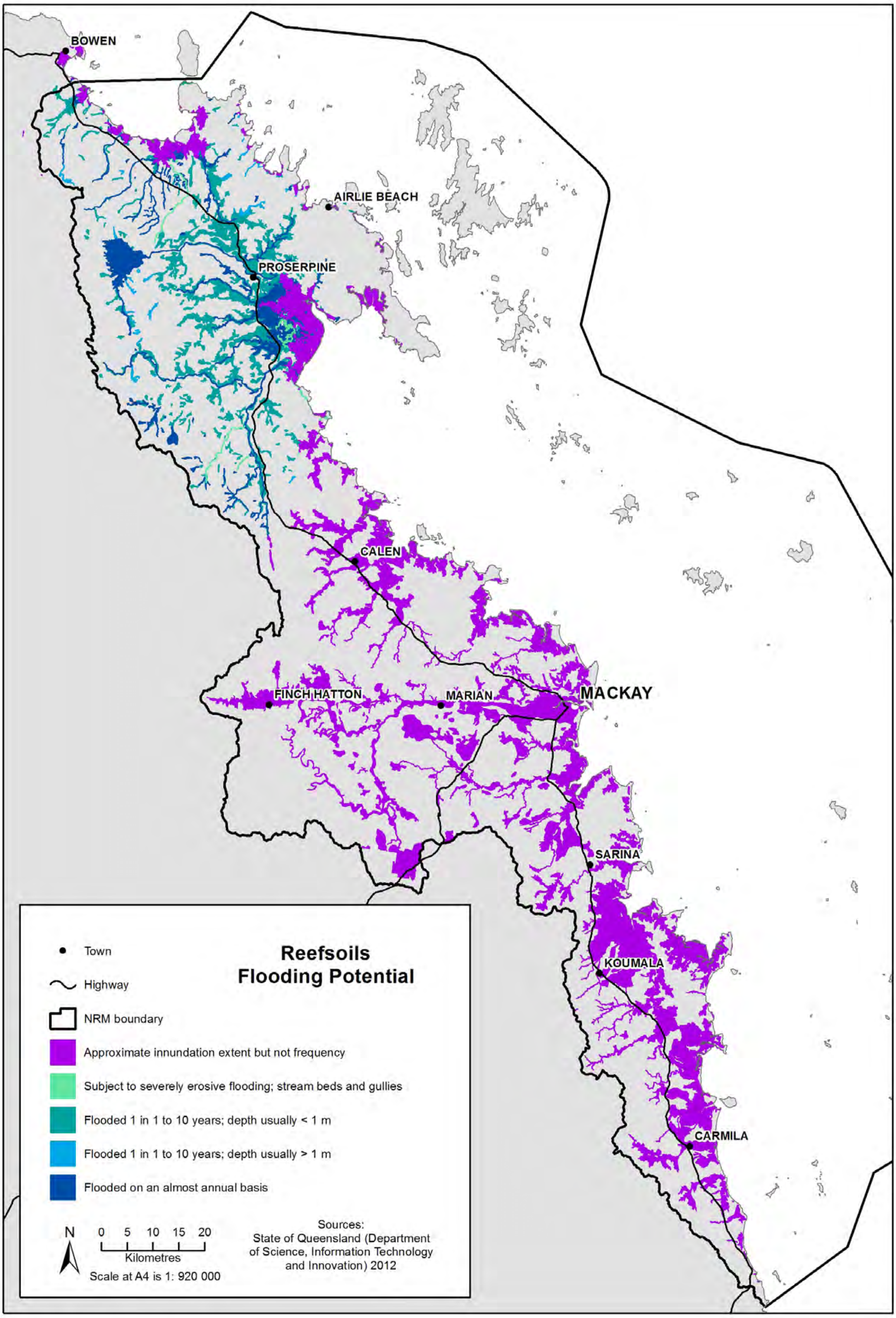
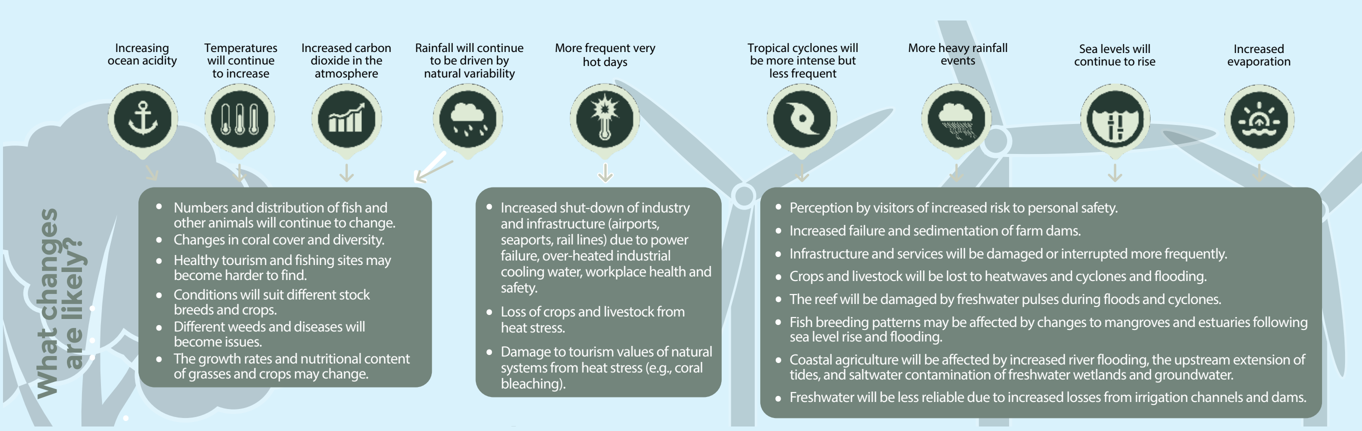


Figure 4.4 *Existing flood risk in the MWI NRM region.*



Sustainable industries

Climate change may mean that different management practices are needed to cope with changed climatic conditions and weed issues. It is likely that industries will need to develop around new crops, stock breeds and commercial fish species, and that tourism, milling and other industries will also be affected.

Changed rainfall and increased ocean acidity, increased sea surface and average temperatures and atmospheric carbon dioxide

Warmer and more acidic ocean waters will change the numbers and distribution of fish and other marine organisms, as well as the amount and diversity of coral. Warmer water temperatures also risk increasing the number of coral bleaching events, which will eventually result in the death of extensive areas of the reef, if bleached areas do not have time to recover before subsequent high temperature events. These changes present substantial risks to the commercial fishing and reef tourism industries.

Different rainfall patterns and temperature conditions will affect the breeds, varieties and species of stock and crops that are currently most suited to the region. There is a considerable risk that some current industries may not remain viable as climatic conditions continue to change. It is also likely that the growth rates and nutritional content of pastures and crops will change with increased atmospheric carbon dioxide levels, though the specific changes it can expected that detailed consideration for each industry in the region. The types of weeds and diseases that are currently problematic for agricultural industries may also change, either as they respond to the changing climate, or because new agricultural products have different pest problems. Again, it is important to evaluate these risks for each industry in the region.

It is likely that current benchmarks for best management practice will need to change as the climate changes. For example, as freshwater availability is likely to decline and evaporation from crops and pastures will increase (see section i) above), new water-efficiency measures will be needed.

More frequent and warmer hot spells

There is substantial risk to primary industries of losses from heat stress in crops and livestock during heatwaves. In sugarcane, the rate of photosynthesis declines rapidly in temperatures above 34°C (Sugar Research Australia, 2013) which may impact on ability of the plant to transpire. The risk to corals increases during heatwaves, when high temperatures cause bleaching events; corals can often recover from bleaching events, but prolonged or repeated hot spells usually cause coral death. In 2016 and during the finalising of this Plan, a mass coral bleaching event is taking place in the more pristine northern parts of the Great Barrier Reef. This event is linked directly to ongoing high SST's and demonstrates the consequences of extreme temperatures on natural ecosystems.

More frequent and warmer hot spells will increase the risk of industrial shut-down, which will directly impact those industries, as well as other operations dependent on them. Existing workplace health and safety regulations would lead to shut down of mines, air- and sea-ports during heatwaves, leading to interrupted supply of petroleum and export of sugar, grain and coal. The risk of large-scale power failure increases during heatwaves, with implications for any industry dependent on the power grid. As described above, the risk of overheated industrial cooling water increases with rising temperature and more frequent and hotter heatwaves.

Higher sea levels, intense rainfall events and tropical cyclones

More frequent and/or extreme weather events can change tourists' perception of the safety of the region. Impacts on tourism will be compounded by any damage to the health of the Great Barrier Reef, such as those resulting from large pulses of freshwater during flood events, heatwaves and damage caused during intense cyclones. Considering the importance of the international and domestic tourism industries to the region, these risks are substantial to the economic sustainability of the region.

Higher sea levels, floods and cyclones impact on wetlands, seagrass beds and mangroves. This will affect breeding and other processes in fish, and risks significantly impacting commercial fishing operations.

Risks to primary industries include direct loss of crops and livestock during heatwaves, floods and cyclones, greater disruption in farm activities such as harvesting, increased soil erosion with intense rainfall events, increased failure and sedimentation of dams and damage to farm and other critical infrastructure. As described above, coastal agriculture may be affected by increased river flooding, inundation from sea level rise, the upstream extension of tides and the intrusion of seawater into coastal wetlands and groundwater. This may mean that current agricultural production in some low-lying areas (e.g., sugarcane) will no longer be possible, or will only be possible using salt-tolerant varieties or products. Further, nutrient management with respect to nitrogen-based fertilisers in areas subject to waterlogging may need to change. The use of readily-available nitrogen formulations (such as urea) in waterlogged soils will produce the greenhouse gas nitrous oxide and may attract penalties.

Heavy rainfall events are likely to be associated with increased soil erosion, with implications for land use, especially grazing and urban development. Areas currently at risk from soil erosion have been mapped throughout the region (Figure 4.5).

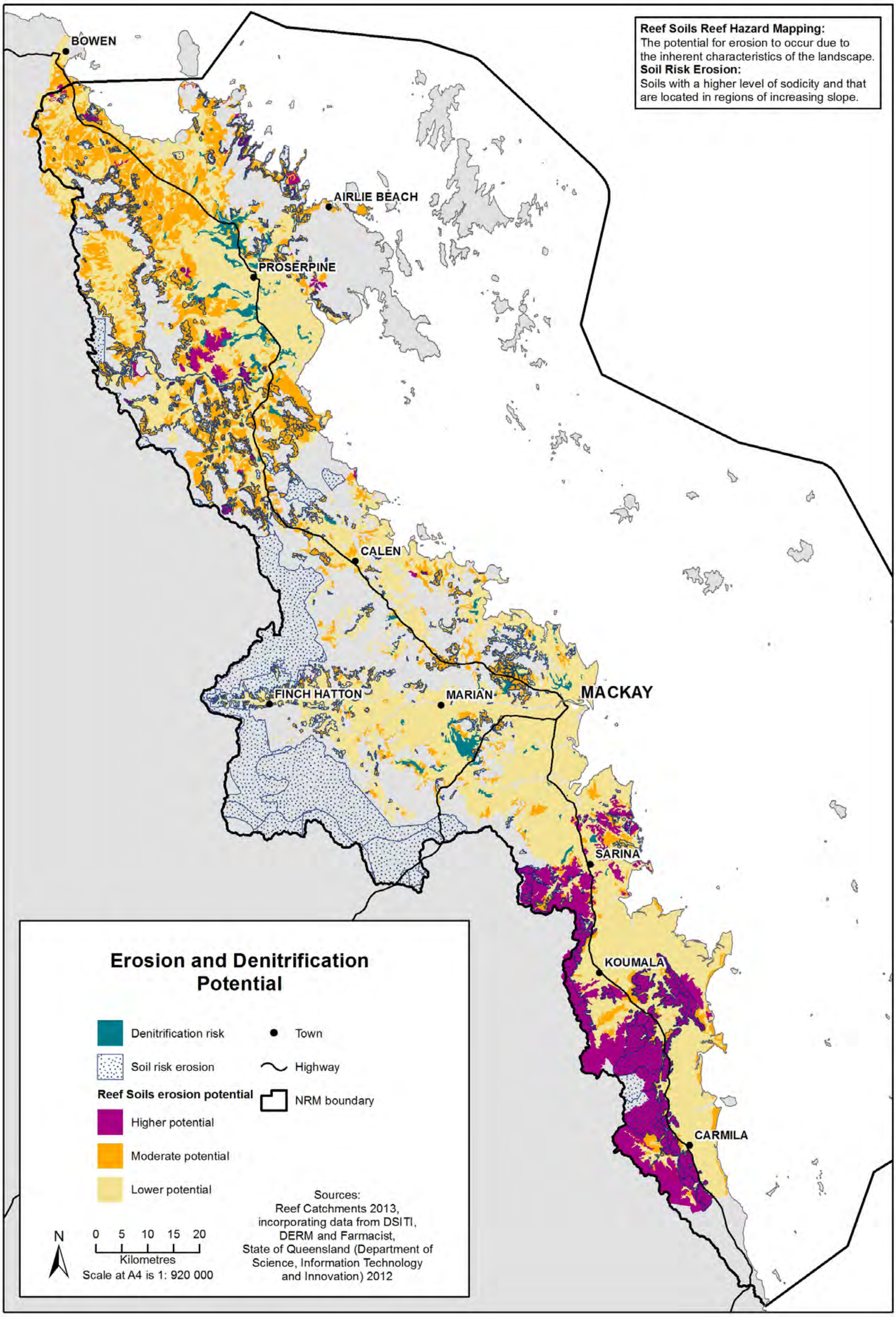
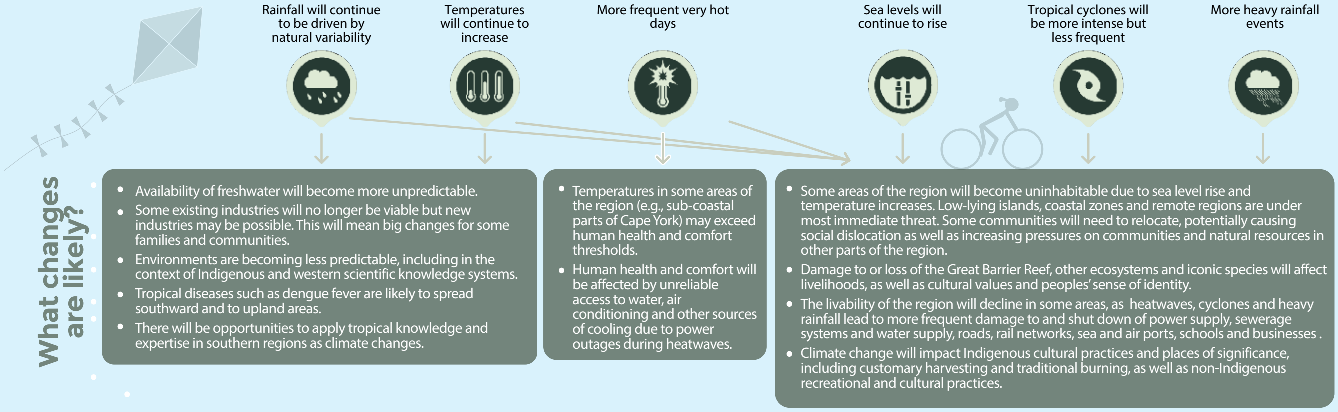


Figure 4.5 *Areas currently at risk from soil erosion and denitrification in the MWI NRM region.*



Healthy communities

The climate may become less comfortable for communities in the region, especially as heat waves become more common. On the other hand, the climate of the region will remain relatively attractive, compared with many other areas. There will be increasing risks of tropical diseases in the region, and substantial changes to industries and livelihoods. Sites of cultural importance to Traditional Owners and other people are being lost, and the ability to perform various cultural practices may be reduced.

Changed rainfall and higher temperatures

As described previously, the predictability and availability of freshwater is likely to decline, impacting the supply of town water and therefore water restrictions may be more common in urban areas. Other communities that rely on rain or groundwater for domestic supply may need to increase water tank capacity. In brief, communities are likely to have less access to freshwater.

There is a substantial risk from increased outbreaks of tropical, vector-borne diseases such as dengue fever, which are projected to occur further south and at higher altitudes as temperatures continue to increase.

Changes in industries will have substantial consequences for some families and communities. The region is currently experiencing rapid and substantial changes due to changes in the resources sector. Government support for transition to sustainable industries rather than those that follow boom-and-bust cycles will facilitate improved economic and social sustainability in the region. It will be essential for all levels of government to develop appropriate policy and provide good support to affected people to manage transitions from current industries or practices. There is also a risk to peoples' sense of place and connection to the region, as the environment becomes less predictable from their knowledge which is based on personal experience, in many cases gained over a lifetime or generations of family connection. It is clear that Indigenous peoples' knowledge systems are being affected as environmental signals recognised through many generations of experiences are affected by the changing climate.

Rising sea levels, intense cyclones, extreme rainfall and heatwaves

RPS Australia conducted an assessment of social vulnerability and resilience for the region as part of the consultancy project for Reef Catchments 'Natural Resource Planning for Climate Change Mackay Whitsunday Region' (RPS, 2014). The approach used is based on Griffith University's VAMPIRE mapping methodology and uses 2011 Australian Bureau of Statistics data for stakeholder circumstances. This approach is consistent with vulnerability assessments used elsewhere in Australia (e.g., CSIRO's Mapping Climate Change Vulnerability in the Sydney Coastal Councils region, Griffith University's Unsettling Suburbia: The New Landscape of Oil and Mortgage Vulnerability in Australian cities and the Local Government Association of South Australia's Guidelines for developing a Climate Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment). The map indicates human populations which have high sensitivity and therefore most probably low adaptive capacity to changes in climate (Figure 4.6). As the social vulnerability assessment has been conducted as a desktop study and has not been assessed locally this figure should be interpreted with caution and updated with local knowledge. Vulnerability of Traditional Owners is also not reflected in this assessment and is discussed later in this section.

There is high risk to communities in vulnerable areas of MWI, especially those in low-lying coastal areas. It is likely that settlement in many coastal areas will be challenged by seawater inundation, increased flooding and intense cyclones. The insurance industry has already identified areas within 50km of the coast as high risk, partly due to the projected impacts of climate change, and premiums are increasing accordingly. Without adequate consultation and land use planning and policy, the risks and costs to people living in these communities will increase. Relocation of coastal settlements and infrastructure is an adaptation strategy that is being seriously considered throughout the world, but this will require a participatory consultation process to minimise social dislocation, conflicts over land use in other parts of the region, and unintended maladaptive outcomes.

There is considerable risk to the liveability of communities in the MWI region, with more frequent shut-down of power supply, damage to services such as sewerage and water supply systems, and access to services such as hospitals, schools and businesses. For example, there is a high risk of power failure during heatwaves, which will affect peoples' access to water, air conditioning and other sources of cooling.

Traditional Owners of the region (including Yuibera, Koinmerburra, Ngaro, Gia) have higher vulnerabilities to climatic changes than the general population in regional centres. They may live in regional centres but as traditional custodians of land and sea country they have a cultural connection to country. The lack of co-management and involvement in decision-making in the region reduces their ability to access and look after places that are important to them. Most Traditional Owners of the region were dislocated in the past and live elsewhere as opportunities to stay close to country (e.g. through employment) are limited in the local region. Further damage to land and sea country through climate change is increasing their vulnerability. This includes through loss of places for crabbing and fishing, damage and or loss to seagrass that supports culturally significant species (dugongs and turtles) and potential loss of coastal freshwater wetlands. Damage to or loss of the Great Barrier Reef and other natural systems will not only affect livelihoods but also peoples' cultural identity. Koinmerburra and Yuibera Traditional Owners have documented where artefacts and places of special cultural significance are already becoming inundated or eroded by extreme weather events. Further, a likely impact of rising sea levels is the landward migration of mangroves into saltmarsh communities. There is evidence that this is already occurring in the region at Cape Palmerston; an area of special significance to Yuibera and Koinmerburra peoples. Climate change will also affect customary harvesting of bush foods and medicines.

Non-Indigenous members of the MWI region will also be impacted by changes in recreational and cultural practice. This may include the inundation of or damage to coastal boat ramps which will substantially reduce peoples' ability to safely launch marine craft.

However, while projected changes in the MWI region are substantial, more deleterious changes are projected for other parts of Australia and the world, including substantial drying and warming. It is likely that the MWI region will remain relatively attractive as a place to live, work and undertake primary industries, and this may mean that the region's population will continue to grow, even beyond projected levels. Large and rapid population growth will potentially increase pressures on land use, water supply and social cohesion.

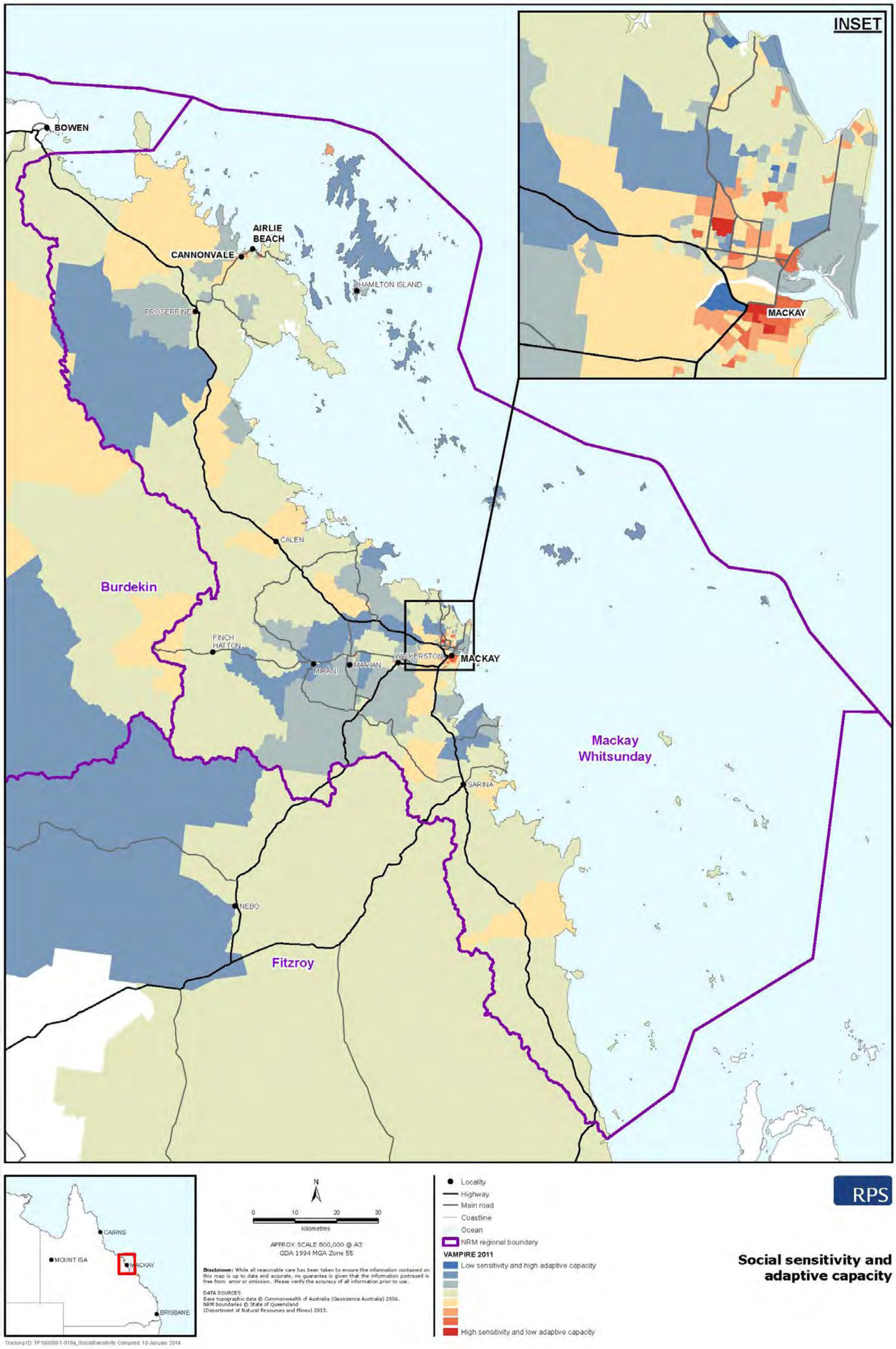
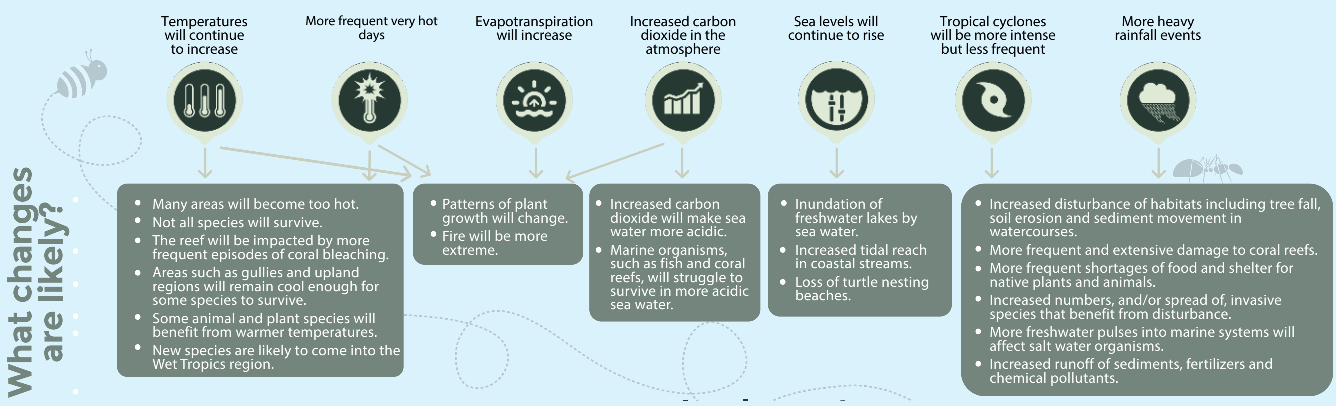


Figure 4.6 *Social sensitivity and adaptive capacity for the MWI NRM region*



Biodiversity and ecosystems

Natural systems are extremely vulnerable to climate change. The numbers, types and distribution of plants and animals will change from what we currently recognise as 'natural.' Some species will no longer be able to survive in the region, while other new species may move in from other areas. Areas that will remain fairly cool are likely to play a very important role in providing refuge for many species.

Changed rainfall and increasing temperatures, heatwaves, evaporation and atmospheric carbon dioxide

Some areas of the MWI region will become too hot for the plants or animals that currently live here. In some cases, these plants and animals may be able to survive in cooler areas, such as at higher altitudes or in gullies and along streams. Scientists refer to these areas as 'refugia' (see Chapter 5). It may be possible for plants and animals to survive in the MWI region in refugia, though this depends on:

- whether or not suitable habitats are available in these areas;
- the presence of other species that compete for available resources or are predators; and
- ability to physically get there.

Analyses based on temperature and rainfall for the MWI region show that there may be nowhere within the MWI region with suitable climate for certain vertebrate species that currently occur here (Reside, unpublished data, see Chapter 6). The area of suitable habitat for a few animal species may increase in the MWI region including for some species that move in from neighbouring regions as the climate becomes unsuitable for them in those areas. On a national scale, the MWI region and other areas of north-eastern Australia are recognised as being important for many animals that currently live in neighbouring regions that are becoming increasingly hotter and drier (Reside et al., 2013). For some organisms, even if they can tolerate the higher average temperatures, prolonged extreme temperatures during heatwaves will cause widespread mortality.

For marine organisms, the increasing acidity of ocean water (due to increased atmospheric CO_2) will have negative consequences, reducing the survival and growth rates of fish, molluscs and coral reefs. As described earlier, heatwaves will lead to more extensive and regular coral bleaching. Increasing average temperatures are already associated with substantial southward shifts in the distribution of some tropical fish species (e.g., Figueira & Booth, 2010).

It is likely that the region will be faced with new plant and animal communities containing combinations of species that are different to what is currently recognised as 'natural.' This is because species that currently occur together may be affected differently by climate changes, or they may respond differently. For example, with plants, the effect of increased atmospheric CO_2 on growth rates will vary between plant species and will depend on interactions with other climatic changes. As with animals, some areas may become too hot for certain plant species to survive in the MWI region, others will be able to persist in refugia, and new species are likely to move into the region. Specific analyses for plant species (or ecosystems) in the region are not available at this stage. Broader-scale analyses based on understanding of the relationships between climate and vegetation suggest that vegetation communities will change. Research at the national scale by Hilbert and Fletcher (2010) predicts a general decline in forest communities and an increase in drier, more open woodlands, shrublands and grasslands. However, the climate is changing more quickly than vegetation can respond, meaning that many plants are likely to be stressed in the environments where they occur. This is likely to affect things like the ability of plants to reproduce under new climate conditions.

Fire will be a key factor in determining change in vegetation patterns. It is predicted that fire behaviour will become more extreme, especially in areas where bushfire is a current risk (Figure 4.7). The MWI NRM Plan (2014) identifies many parts of the region as being under high to very high threat from fire. These include areas in the Clarke Connors Range and along the hinterland plain around Calen and Seaforth, parts of Dingo beach and Hideaway Bay, Whitsunday and Hook islands, in production forestry west of the Bruce Highway in the Mackay, Sarina and Isaac regions. Bushfire risk also depends on fuel development during the previous season and the longer-term burning regime. Fire management regimes for fire hazard reduction and biodiversity protection have been developed for different parts of the landscape in the MWI NRM region (Reef Catchments, 2013a) and implementation of these regimes is intended to help manage bushfire risk.

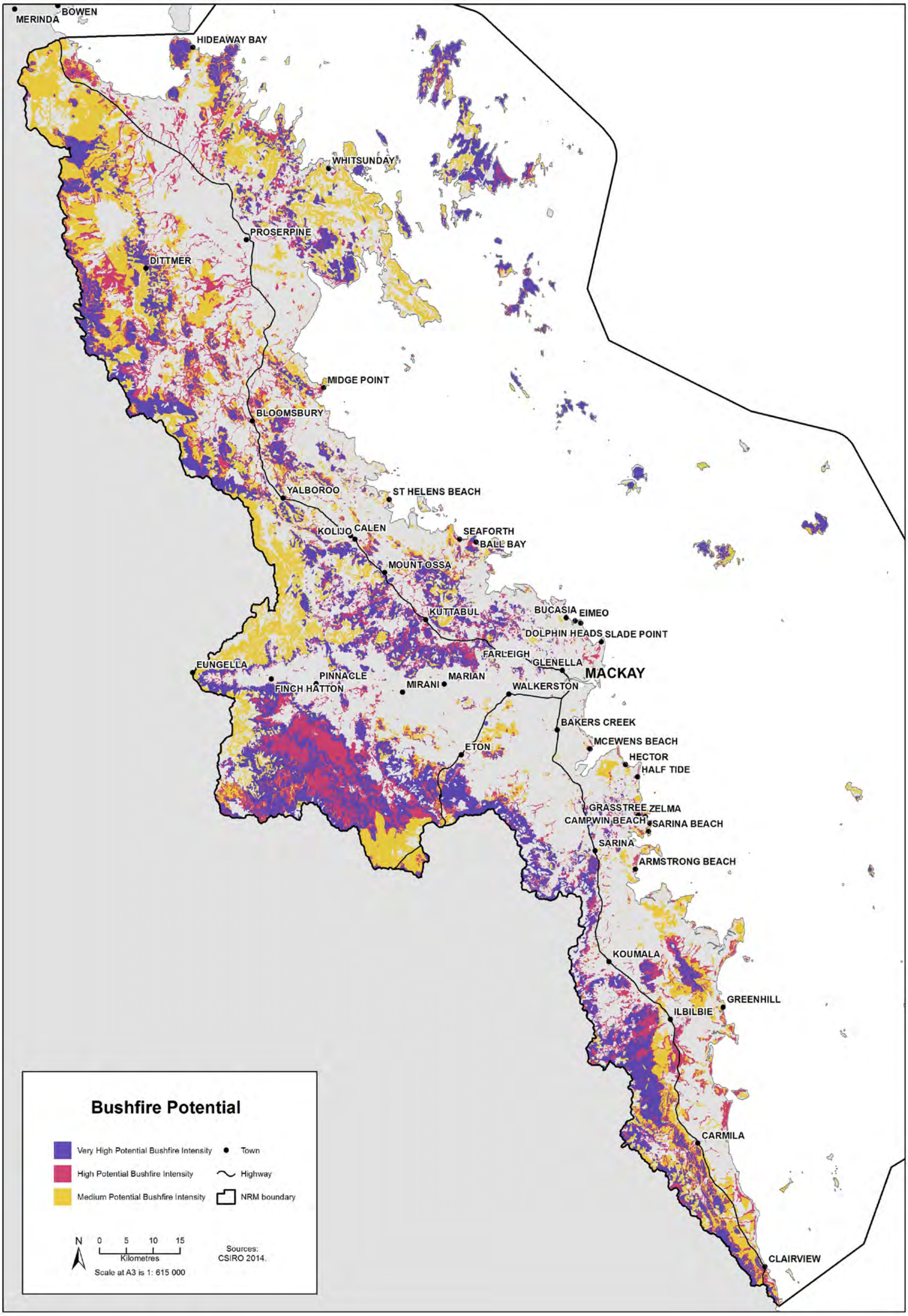


Figure 4.7 *Bushfire risk in the MWI NRM region. Source: Queensland Government*

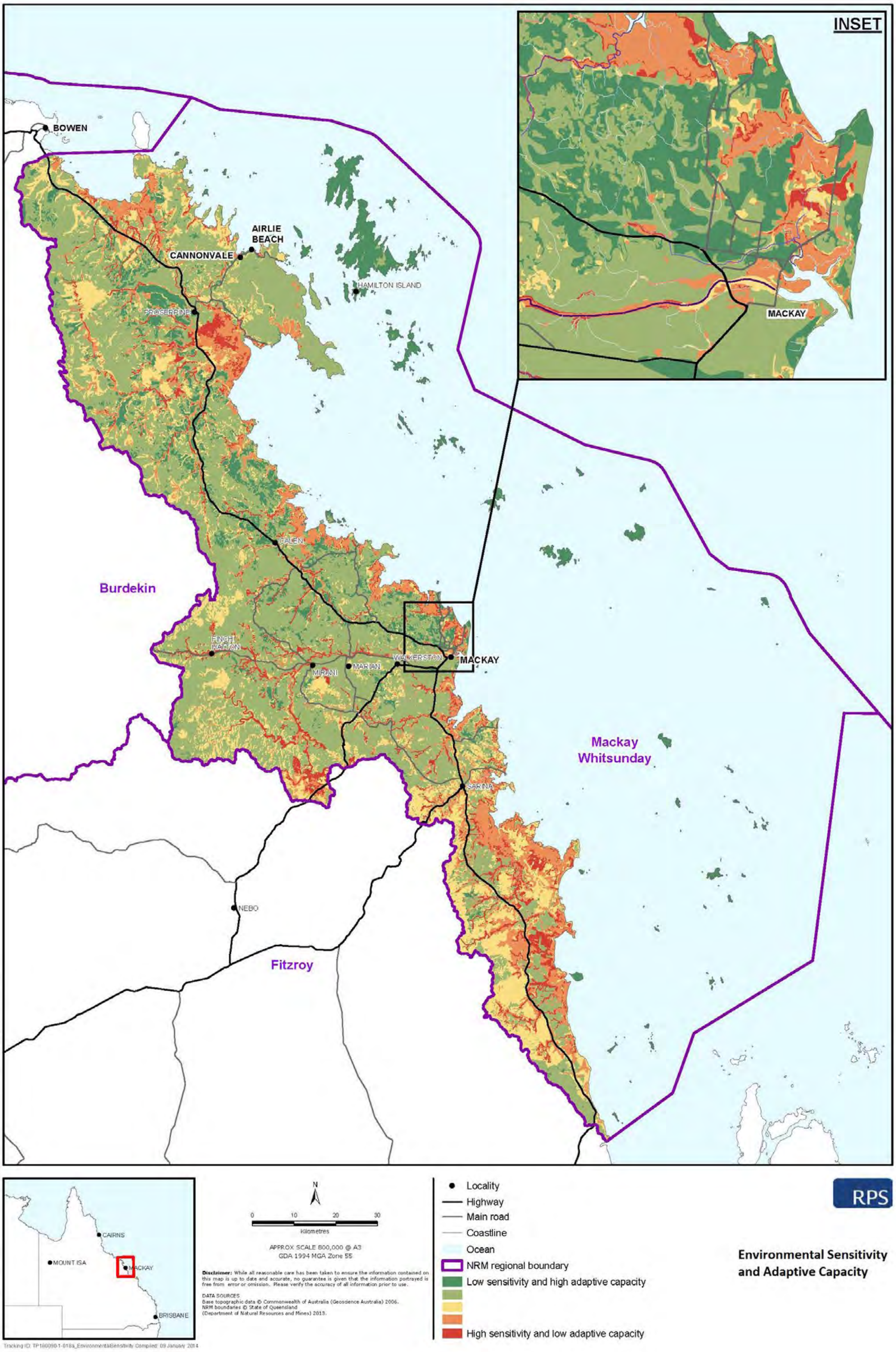


Figure 4.8 *Environmental sensitivity and adaptive capacity for the MWI NRM region. (Source: RPS 2014))*

Rising sea levels, intense cyclones and extreme rainfall

RPS (2014) also examined environmental sensitivity and adaptive capacity as a part of their report to Reef Catchments (Figure 4.8). This map indicates selected natural systems and conditions, which have high sensitivity and therefore most probably low adaptive capacity to projected changes in climate. This broad examination of environmental sensitivity indicated that the natural environs of the McCready Creek Reserve, Proserpine River, Gregory River and Cape Palmerston National Park have the greatest sensitivity and likely least adaptive capacity to a changing climate. Additional information in how Figure 4.6 and 4.8 were derived can be found in the supporting document RPS (2014).

Seawater will inundate some coastal freshwater habitats, including wetlands, waterways and lakes, with implications for freshwater plants, groundwater dependent ecosystems and animals. In addition to direct impacts on salt-intolerant plant and animal species, there will be a range of indirect impacts. These areas are also important to Traditional Owners. Freshwater wetlands will not tolerate saltwater inundation, and mudflat or mangrove vegetation may colonise these areas over time. This will have implications for the large numbers of wetland species that depend on these systems. Wetlands in the MWI region, such as the Goorganga Plains complex, are recognised as providing nationally-important habitat for plants and animals, including habitat for international migratory birds. Sea level rise and flooding will also alter habitats such as sea grass and estuary systems, impacting on culturally and commercially important marine species such as dugong and fish.

Sea level rise and more intense cyclones in combination are likely to increase coastal erosion, with a range of implications for plants and animals, including the loss of vegetation from sand dunes and headlands and loss of sandy beaches for beaches for turtle nesting and migratory bird roosting areas (Figure 4.9). It is clear from Figure 4.9 that areas currently important to migratory birds will be lost to rising sea levels and heavily impacted during storm surges.

Increased flows in streams/ rivers associated with more extreme rainfall events will modify freshwater aquatic ecosystems through bank and channel erosion. This will impact on aquatic habitat and refuges through removal of deep water areas, habitat and loss of connectivity.

Cyclones and extreme rainfall are significant agents of disturbance to habitats in the region. Natural systems have many strategies for responding to disturbance, but with more frequent disturbance – especially in the context of a changing climate and landscapes that have already been extensively cleared, modified and developed - the capacity for resilience in the face of more frequent and intense disturbance is uncertain. It is likely that more intense cyclones will cause more extensive and frequent damage to coral reefs and result in more regular shortages of food and other resources for animals. More intense, extensive and frequent flooding will result in increased runoff of soil and chemical pollutants into waterways, as well as pulses of freshwater into marine systems. More frequent disturbance is also likely to favour invasive species.

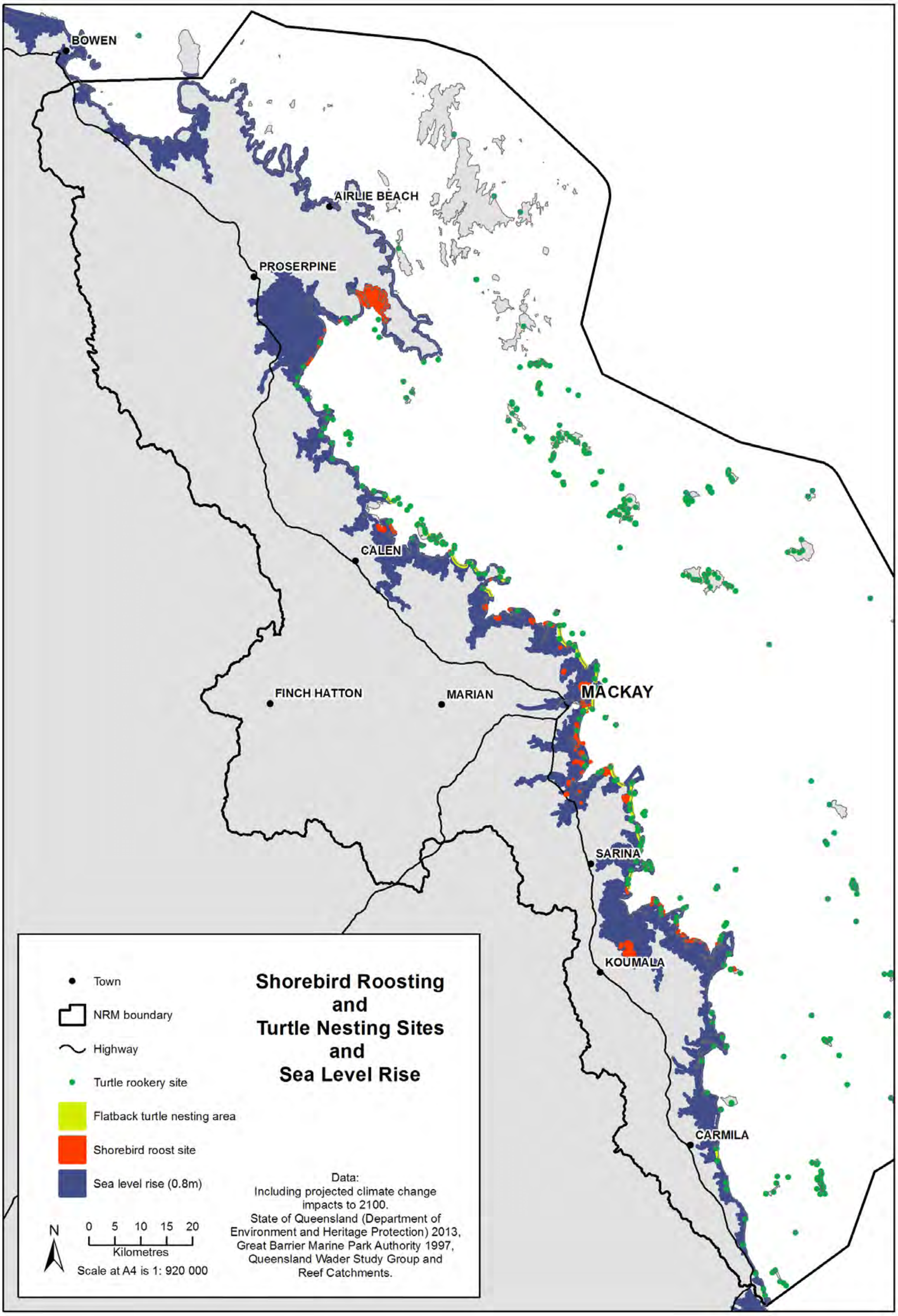
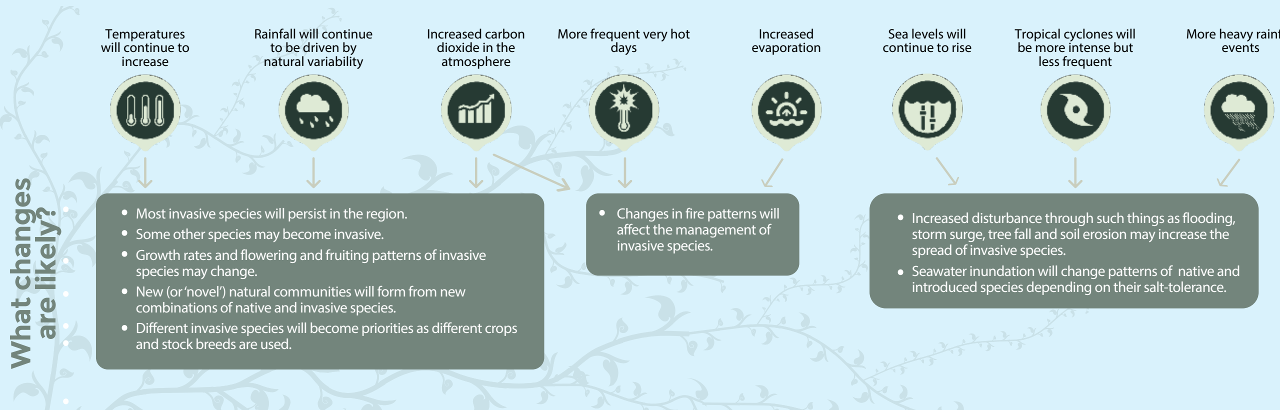


Figure 4.9 *Existing migratory bird roosting areas in the region. Also shown are areas affected by projected 0.8 m sea level rise by 2100, together with area affected by storm surge with 0.8 sea level rise. There is a lack of information on turtles and shore birds in the Whitsunday and Isaac regions because of no surverys.*



Invasive species

Scientists expect that most of the environmental weeds that are currently a problem will remain a problem under future climatic conditions. More common and intense extreme events will help the spread of invasive species. New species may also emerge as problems.

Changed rainfall, increasing temperatures and atmospheric carbon dioxide

Scientists expect that environmental conditions will remain suitable for most of the invasive species that currently occur in the region, however new species may become a problem as the climate changes. This could include species that are 'sleeper weeds' (i.e., introduced to the MWI region but not currently considered invasive or problematic) that are favoured by future climatic conditions, or species that come in from other areas, including from outside Australia. In addition to different species being advantaged by new climate conditions, different invasive species may become higher priorities for management with changing climatic regimes or when different crops or livestock are introduced as part of adapting to climate change.

Future climatic changes may increase or decrease distribution of invasive species in the region. There are currently a range of priority invasive species for the region including lantana (*Lantana camara*), rubber vine (*Crytpostegia grandiflora*), Giants Rat Tail grass (*Sporobolus pyramidalis*), cat's claw creeper (*Macfadyena ungus-cati*), Hymenachne amplexicaulis and Mimosa pigra, which is currently contained around the Peter Faust dam. A national project funded under Stream 2 of the NRM planning for climate change program AdaptNRM has developed a framework for planning weed management under climate change and delivered results of modelling of future environmental (climatic) suitability for a suite of major weed species http://adaptnrm.csiro.au/invasive-plants-climate-change/). AdaptNRM provide information on changes in environmental suitability for four of the six priority weed species for the MWI region listed above: for lantana and Mimosa, models show little change, while for rubber vine a small increase and for cat's claw creeper a decrease in climatic suitability in the region. However, in addition to climatic suitability, a large number of management factors (e.g. management choices, soil type) will influence future weed distributions, and these models should be used carefully in decision-making.

The Mackay Regional Pest Management Group (MRPG) was established in 2002 and consists of representatives from local and state government departments, community groups and industry bodies whose core business is to provide pest management information and expertise within their respective fields (http://www.mackayregionalpestgroup.org.au/). The group develops a Regional Pest Management Strategy periodically. Ongoing support to this Group to manage existing and potentially new incursions of invasive species as the climate changes will be crucial. This group will potentially play a critical role in monitoring actual, on-ground changes in invasive species' distributions or numbers in the region.

Rising sea levels, intense cyclones, extreme rainfall, bushfire

Extreme events are major agents of disturbance and are associated with the spread of invasive species. As the intensity of cyclones, extreme rainfall and bushfire are projected to increase, it is reasonable to expect that opportunities for the establishment and spread of invasive species will also increase.

SUMMARY

There is considerable existing vulnerability to climatic events in the MWI region. Vulnerability will increase as climate change continues, in particular with more frequent and/or more intense extreme events. The impacts will be far-reaching and will affect all sectors, and the whole MWI community. In general, it is expected that there will be reduced availability of freshwater, that existing land management practices and primary industries may become unviable, that the liveability of some areas will decline, that biodiversity will not be able to survive in all current locations, and that there will be new invasive species issues. Successful adaptation to these impacts will require inclusive planning (for climate change and to ensure it does not exacerbate existing inequities) and ongoing monitoring of changes on-the-ground.

CHAPTER 5

Potential adaptation options for the MWI NRM region

There is already significant climate vulnerability in the MWI NRM region and the increased risks associated with impacts from projected climate change have been discussed in detail in Chapter 4. Even if global emissions were dramatically reduced in the very near future, greenhouse gases already emitted will persist in the atmosphere for decades or centuries, leading to substantial climate change. Planning for adaptation to these unavoidable changes in the climate system is an immediate need.

Climate change is not only an environmental or natural resource issue; it is an issue for human wellbeing. One of the key adaptation actions required for the MWI region is to increase general awareness of the need to develop adaptation responses and opportunities to get involved in adaptation planning. Reef Catchments' process of developing this plan represents a substantial first step in this regard, but wide-reaching engagement and education will need to continue and is the responsibility of all organisations.

Adaptation, not maladaptation

Climate adaptation responses can be considered in three categories: 'protect', 'accommodate' and 'retreat'. Table 5.1 provides some examples to illustrate the differences between these categories.

Table 5.1 *Protect, accommodate and retreat categorisation of climate adaptation responses, together with 'hard' and 'soft' options for each category of response. (After Fletcher et al., 2013)*

	Protect	Accommodate	Retreat
	Use hard or soft defensive measures to enable continued use of vulnerable areas	Adjust living, working and operating patterns to continue operating in vulnerable areas	Withdrawal from vulnerable areas
Example 'hard' options	Dikes, seawalls, groynes, breakwaters, storm tide barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocate or abandon threatened assets
Example 'soft' options	Beach nourishment, dune restoration, revegetation	New building codes, public disclosure, early warning and evacuation systems, risk-based hazard insurance	Land use restrictions, building setbacks, rolling easements

Because climate change impacts affect all sectors, including primary industries, development planning, water management, biodiversity, and individuals, adaptation to climate change requires substantial and wide-reaching change. This will require ongoing work across sectors to ensure that actions taken to support adaptation in one sector do not come at the cost of substantially increasing the vulnerability of other sectors; this 'cost' is termed maladaptation. Some examples of adaptation measures and their potential benefits as well as the potential costs (ecological, social, and cultural) are provided in Table 5.2. Mitigation is where efforts are made to reduce greenhouse gas emissions in order to avoid unmanageable impacts of climate change. Certain actions in mitigation may also have perverse or maladaptive outcomes if consequences of the action are not considered carefully; examples of these are also included in Table 5.2.

Economic costs have not been estimated; most options will involve economic costs and these would need to be calculated on a case-by-case basis. This information is not comprehensive but intended as a guide to assist in cross-sectoral negotiation of mutually agreed adaptation actions and pathways. This will likely also require independent analyses of local and regional costs and benefits of projects, together with their contribution to mitigating greenhouse gas emissions or improving adaptation to climate change.

Table 5.2 *Examples of potential adaptation and mitigation responses to specific climate change impacts, together with potential costs to other sectors. The potential adaptation responses in this table are not necessarily endorsed by Reef Catchments or by the MWI community, nor are the potential benefits and costs comprehensive. This information is provided to illustrate potential maladaptation outcomes associated with various options. Responses are categorised as protect, accommodate and retreat (Table 5.1, above). Note that there are several impacts for which there may be no 'protection' adaptation options.*

Impacts	Potential adaptation response	Potential adaptation benefits	Examples of potential costs to other sectors
Sea level rise causing upstream tidal penetration	Tidal gates on coastal waterways	Restrict upstream extent of tides	Prevent adaptation of mangroves establishing upstream. Inhibit movement of in-stream fauna; impact on fisheries and fish passage. Land recovered from using dykes can be valuable to offset cost of dykes. New coastal land
Sea level rise inundating coastline areas or increasing erosion	Sea walls, dykes, storm surge barriers, break walls	Prevents or reduces seawater from reaching shoreline.	May create erosion problems elsewhere. May exacerbate river flooding by inhibiting outflow to ocean. Potential loss of nesting areas for turtles through loss of sandy beaches. Barrier to movement of aquatic fauna. Reduce coastal aesthetics.
	Construct dunes	Prevents or reduces seawater from reaching shoreline.	May impact sand extraction areas. May impact on turtle nesting beaches.
	Elevate buildings and infrastructure in low-lying coastal areas	Reduces vulnerability of infrastructure.	Cost of adapting some infrastructure (e.g. sewage systems) may be higher than relocating
	Relocate buildings and infrastructure to higher or more inland locations	May increase landward connectivity for coastal animals and plant communities.	Ongoing impact of 'urban heat effect' if sustainability principles (e.g. green space, water sensitive urban design) are not incorporated into new settlements - leading to increased energy usage and increased GHG emissions. Inability to pay bills for increased energy usage. Potential loss of critical habitat for plants and animals, include essential climate refugia; further loss of good quality agricultural land and places of cultural significance. Ongoing pollution of rivers and streams.
Sea water contamination of coastal groundwater due to sea level rise	Recharge of a sea water to ground water	Increases salt water contamination of ground water	
	Desalination	Removes salt to provide fresh water	Increased use of electricity desalination plant, potentially increasing GHG emissions and increasing the cost of living if energy costs are high. Loss of or damage to environmental and cultural values due to infrastructure construction. Increased cost of water to consumers.
	Source freshwater from new, unaffected areas	Maintain access to freshwater in affected locations	Reduce environmental flows Loss of or damage to environmental and cultural values and agricultural land due to dam and infrastructure construction

Impacts	Potential adaptation response	Potential adaptation benefits	Examples of potential costs to other sectors
Sea water inundation of fresh water bodies due to sea level rise	Sea walls, dykes etc.	Reduces sea water contamination of coastal water bodies	May create erosion problems elsewhere. May exacerbate flooding by inhibiting outflow to ocean. Potential loss of nesting areas for turtles through loss of sandy beaches. Barrier to movement of marine fauna. Reduce coastal aesthetics.
	Switch to salt-tolerant crops.	Able to produce crops under new conditions	
	Desalination	Removes salt to provide fresh water	Increased use of electricity for desalination plant, potentially increasing GHG emissions and increasing the cost of living if energy costs are high. Loss of or damage to environmental and cultural values due to infrastructure construction. Increased cost of water to consumers.
	Source freshwater from new, unaffected areas	Maintain access to freshwater in affected locations	Reduce environmental flows Loss of or damage to environmental and cultural values due to dam and infrastructure construction
Increased average temperatures and extreme heat	Increase access to and use of air conditioning Green Street (e.g. trees)	Maintains human health and comfort in current locations Maintains human health and comfort in new locations	Increased use of electricity, potentially increasing GHG emissions and increasing the cost of living if energy costs are high
	Design or retrofit buildings to be cooler	Maintains human health and comfort in current locations	
	Relocate to cooler locations	Maintains human health and comfort in new locations	More human settlement in these areas may reduce availability of critical upland refugia for biodiversity.
Increased evaporation of stored water	Physical or chemical covers, wind screening, adapted design	Maintains or increases access to fresh water	Potential for adverse environmental and health effects of chemical covers.
	Reduce demand by increasing efficiency in water use, reuse and recycling, storage in underground aquifers	Maintains or increases access to fresh water	
	Build additonal dams	Maintains or increases access to fresh water	Loss of or damage to environmental and cultural values and agricultural land due to dam and infrastructure construction
	Localised water collection and distribution	Maintains or increases access to fresh water	More difficult to monitor water health indicators.

Impacts	Potential adaptation response	Potential adaptation benefits	Examples of potential costs to other sectors
Flooding from intense rainfall events	Drainage channels, bunds	Reduces flooding in target areas	May exacerbate flooding elsewhere.
	Elevation of buildings and infrastructure	Reduces flooding in target areas	
	Relocate from floodplains and other low-lying areas	Reducing human settlement in lowlands may provide opportunities for restoration of habitats for biodiversity	More human settlement in other areas may reduce current and future habitat for biodiversity
Increased damage to power supply and distribution from cyclones and heatwaves	Develop back-up power supplies	Limit impacts of loss of power	Increased costs to Local Governments for running sewage and water from generators
	Replace wooden power poles with stronger materials	Limit damage to poles.	Increase greenhouse gas emissions associated with steel production, or production of other materials. Does not address damage to wires.
	Develop underground distribution network.	Not vulnerable to damage during cyclones and storms	Vulnerable to underground inundation and to rising water table and salination in coastal areas.
	Develop localised generation and distribution networks	Readily based on renewable energy sources such as wind, solar and tidal flow generation (e.g. ocean buoys).	
Green energy	Agricultural land transitioned into energy crops for green biomass	More energy produced from renewable sources	Loss of throughput to sugar mills, potentially impacting on mill viability.
	Cropping focus of biomass for greatest potential for carbon storage (or sequestration)	More energy produced from renewable sources	Further loss of biodiversity. Increased 'mining' of soils and need for increased nutrient inputs to maximise growth. Increased risk to GBR from eutrophication from terrestrial runoff

Abbreviations: *GHG is greenhouse gas; GBR is Great Barrier Reef*

Potential adaptation options for NRM sectors

The pervasive nature of climate change impacts has the benefit of making everybody a 'stakeholder.' Indeed, workshop participants identified strong connectedness across many or all sectors in relation to the key issues facing them and a willingness to develop integrated responses. As described above, adaptation action in one sector may not support - or may even hinder - adaptation in another. The risk of this is particularly high for biodiversity. Ongoing cross-sectoral discussion is required to negotiate, support and co-ordinate adaptation actions across sectors so that perverse outcomes for other sectors can be avoided. For example, workshop participants identified the importance of increasing interaction with the mining industry because of its substantial influence on factors such as biodiversity, good quality agricultural land, and employment patterns.

In the following sections of this plan, some initial ideas about potential adaptation actions are presented as a starting point for more detailed discussions. In-depth, iterative conversations with regional and local groups will be needed to develop adaptation action pathways that are relevant and feasible for the MWI region. They are not comprehensive, nor have potential trade-offs between options been evaluated. Facilitated discussion with Local government, Traditional Owners, conservation and industry groups and other organisations will identify additional options. Some of the options identified below may not be economically, culturally or socially realistic in the MWI region.

The following text is based on the fact sheets developed by the Wet Tropics Brokering Hub (2015), which in turn are based on discussions during NRM stakeholder workshops across the Wet Tropics NRM cluster region, including in MWI. Most of these options are simply common sense, but now is the time to seriously consider these and other potential responses, and how to incorporate these into practice, planning, education and research. This plan provides additional information and detail on biodiversity as this was focused on in an additional workshop.

The potential adaptation options presented here are intended to be consistent with the principles that emerged during the community engagement process used to develop this plan (described in Chapter 2). In summary, these include:

- promoting industry diversification and viability of existing industries
- facilitating biodiversity protection & ecological connectivity in the landscape
- increasing community resilience in relation to extreme weather
- improving people's sense of belonging, empowerment & being responsible for change
- ensuring food and water security
- increasing Traditional Owner involvement
- developing policy that is strategic, longer-term focused and prioritises public good over private benefit.

Key drivers of change and especially relevant issues:

- Population: i) growth (expect >40% increase by 2031); ii) skills and capacity; iii) transient population (especially with mining)
- Industry growth and decline: i) mining and related (e.g. construction & retail) – decline in Mackay, growing in Proserpine; ii) agriculture – decline in relative importance in the region
- Land use intensification: i) coastal zone; ii) productive land; iii) water quality
- Climate: i) extreme events (more people in vulnerable areas); ii) warming trend
- Government policy, especially how it impacts on the industries operating in the region.

5.2.1 Adaptation options for maintaining fresh water availability

Options for responding to a less predictable - and likely reduced - supply for freshwater include:

- Minimising losses, for example by improving dam design to reduce evaporative loss;
- Reducing water usage, for example by increasing water recycling and reuse programs, or by trialling alternative management practices, breeds and crops to improve water efficiency;
- Increasing domestic storage capacity through the promotion of household rainwater tanks.

Protecting water quality will also be important, and may include actions to reduce runoff of soil, chemicals and other pollutants through more extensive revegetation, or reduced use of fertilisers and so on.

Access to good quality freshwater will also depend on protecting water supply infrastructure. For example, using spatial information about changing risk from sea level rise, storm tide and flooding to locate water storage and distribution infrastructure may reduce the risk of contamination during floods. Siting pumps, pipes and other water distribution infrastructure away from these areas will also reduce the risk of damage and corrosion.

5.2.2 Adaptation options for sustainable industries

The use of spatial information about factors and constraints such as sea level rise, storm tide and flood-prone areas will help to identify increased vulnerability in different parts of the region. Where risks are periodic, adaptation may involve actions such as creating elevated refuges or increasing shading for livestock, or increasing storage capacity for early-harvested crops during the cyclone season. In other cases, industry operations may need to relocate to less vulnerable areas of the region.

New systems are likely to be needed for industries to adapt to changing climatic conditions. These will potentially include the introduction of new crops, breeds or the targeting of different commercial fish species. In turn, these will require new skills, production and processing infrastructure, supply chain and distribution networks, and marketing.

Reducing reliance on expensive inputs, and increasing local markets for goods and service (thereby reducing reliance on transport in and out of the region), may improve the resilience of some industries. Developing backup water and power supplies will also help reduce exposure to interrupted production or operation during cyclones and heat waves.

Finally, community support networks are likely to be critical to help manage the potential social and cultural impacts of transitioning to new industries or practices.

5.2.3 Adaptation options for healthy communities

The use of spatial information for areas vulnerable to sea level rise, storm tide inundation, flooding from heavy rainfall, extreme heat, bushfires and coastal erosion will assist in the (re)location of buildings and infrastructure in areas of lower risk. Ongoing monitoring and modelling of climate trajectories will be critical. Evaluation of alternative potential responses (e.g., sea walls, elevation of buildings, relocation), in terms of their economic, social, cultural and ecological costs, will help to avoid unintended trade-offs, or maladaptation.

The more frequent need for disaster response and recovery will impact emergency services in particular. Adaptation actions may include reducing exposure to extreme weather events, for example by increasing vegetation cover on coastal dunes, building to withstand cyclonic forces and increasing the number of and access to cyclone shelters. In addition, a range of actions may increase resilience in the face of extreme events, including the provision of backup power and water supplies through households of localised networks.

There is potential to take action to address increased health impacts of climate change, for example by promoting building design that reduces exposure to heat and disease vectors (e.g. mosquitoes). Implications for communities of more frequent isolation from healthcare and other services could also be addressed in planning.

Impacts of climate change on cultural values, such as including places of particular significance or traditional practices, may be reduced if these are accounted for in adaptation plans. Industry and community service groups may also be able to provide training, skills, psychological and emotional support.

5.2.4 Adaptation options for biodiversity

Climate change is already impacting on biodiversity. Adaptation is required if plants and animals are to survive and the first step is to reduce the primary threat of vegetation clearing. The more habitat that remains in the MWI landscape, the greater the chance that plants and animals will be able to adapt to climate change. Even if vegetation is currently not core habitat, doesn't support threatened species, and even if it is degraded, it may act as a climate refuge, may provide connectivity so that biodiversity can reach refugia, and it may also support populations for plants and animals that are important for colonising refugia in the future.

Protecting and restoring refugia (see Chapter 5) is likely to be important in enabling adaptation of biodiversity to climate change impacts. However, other actions may be required, such as intervention to promote the establishment, survival, growth and reproduction of species in refugia. This might be because the species are not currently common in the refugial areas (i.e., it's on the edge of their range) or because they currently don't occur in these areas. On-ground action might include the management of predators and competitors. These are complex issues that will require considered thought and discussion and may result in major shifts in how we manage invasive species, fire and other agents of change.

One of the critical challenges will be to develop a working understanding of what we are seeking to achieve with management; it will no longer be reasonable to use historical conditions (e.g. Regional Ecosystems) as benchmarks or reference points. Species will occur in new areas and in different combinations as a result of adaptation to climate change. The scale and rate of climate change is unprecedented and cannot be predicted in any detail as to what the 'new natural' will or should look like. In addition to changes in average temperature and rainfall conditions, extreme events such as heatwaves, floods and intense cyclones will cause more disturbances in the MWI regio. This will interact with changes in the overall climate to influence how plants and animals respond and the proposed management approaches. Monitoring the responses of plants and animals will be key to understanding whether management actions are achieving desired outcomes (i.e. promoting vulnerable species in refugia) and, importantly, not having unintended impacts (e.g. disadvantaging other species). The importance of being able to adapt management to the results of carefully designed monitoring cannot be overstated.

As well as protecting some areas, restoration will be a critical part of climate change adaptation for biodiversity conservation, such as reforestation to provide wildlife habitat and insulate aquatic systems from high temperatures and coral reef rehabilitation. Partnership between researchers and practitioners may promote adaptation by improving understanding of methods of restoring coral reefs or rapidly establishing vegetation cover that has high biodiversity value.

A range of more interventionist strategies is also a potential adaptation response. For example, assisted translocation of species from or into the MWI region is recognised as a potential way of addressing the loss of suitable climate within certain species' current ranges. Also, the uses of artificial cooling (e.g., sprinklers on flying-fox roost colonies) or shade structures are examples of options for intervening to protect plants and animals from climate change impacts.

5.2.5 Adaptation options for invasive species management

Due to the link between disturbance and invasive species, adaptive responses to climate change will most likely make provision for increased need to manage invasive species following floods, fires and cyclones. As with biodiversity, it will be critical that researchers and land managers work together to monitor on-the-ground factors such as:

- actual responses of invasive species to climate change
- the changing impacts of invasive species;
- increasing, new, or declining invasive species in natural and agricultural production areas;
- potential social and cultural impacts associated with changes to invasive species management;
- responses of invasive species to management, including fire and other tools.

CHAPTER 6

Regional priorities for biodiversity and carbon in a changing climate

Natural systems already provide significant carbon stores in the MWI NRM region. As discussed previously the region also has very high biodiversity values that have become fragmented due to human activity and other pressures. The changes locked into the climate system mean increased risk to biodiversity and potential further loss of carbon in the landscape that will contribute to further climate change. Planning for improved outcomes for biodiversity and carbon to these unavoidable changes in the climate system is an immediate need.

Adaptation and mitigation strategies, and actions will be dependent on the sector, where they are located in the local landscape, the inherent hazards and how the risk is likely to change. This was discussed in Chapter 5. Priorities for carbon and biodiversity need to take into consideration the existing patterns of land-use in the region which are shown in Figure 6.1.

Identify refugia for biodiversity

Climate change will fundamentally affect biodiversity because of the close association between climatic conditions (such as temperature and rainfall) and the distribution, growth and survival of plants and animals (See Chapter 4). It is well-understood that biodiversity is extremely vulnerable to the rapid changes in climate that are occurring (IPCC 2007a). There will therefore be a flow-on effect to industries and communities whose livelihoods are intrinsically linked to the natural environment and services they provide (e.g. agriculture, tourism, commercial fishing) in the region (see Chapter 4).

On a national scale, the MWI region is recognised as being one of the most important climate refugia for many animals that currently live in neighbouring regions where it is projected to become hotter and drier (Reside et al., 2013). 'Climate refugia' are areas that will have suitable climates for the plants, animals and habitats of the MWI region. As climatic conditions change, species may no longer able to survive and reproduce in their current locations and will need to take refuge in other areas. Many refugia are at higher altitudes or in gullies and along streams, as these areas are likely to remain relatively cool.

It may be possible for many plants and animals to survive by remaining in or moving to refugia, although this depends on the whether there is suitable habitat in these locations. A common approach to planning for resilience of biodiversity under climate change is to identify climate refugia and prioritise these for protection and restoration. A systematic conservation planning analysis has been conducted for the MWI region (Reside, unpublished data), and identifies those areas of the landscape that currently support suitable climate for most of the region's species, together with those areas that are likely to have suitable climate conditions for most species in the future. Areas that remain suitable, or which become suitable over time are priorities for protection (if they support habitat) or restoration (if they are currently cleared or degraded).

In addition to protecting and restoring areas that are expected to act as climate refugia, it is important to improve the ability of plants and animals to get to these refugia to establish, survive and reproduce. In some cases this may involve movement across substantial areas of the landscape, which could be assisted using corridors or stepping stones (e.g., patches of vegetation that enable species to cross the landscape). Areas of non-remnant regrowth that have high biodiversity value (Butler et al., 2014) can be useful to provide stepping stones to increase landscape connectivity as they are likely to already be acting as climate refugia.

The focus of the rest of this chapter is about biodiversity in the regional landscape and priorities for assisting biodiversity to adapt to climate change; namely priorities for retention and priorities for restoration. This includes information on existing carbon storage in natural systems in the local landscape (Butler et al., 2004) and spatial datasets that have been utilised to determine landscape-scale priorities for biodiversity, connectivity and resilience. Landscape-scale priorities for biodiversity conservation and adaptation are important for planning purposes. Community priorities by regional stakeholders (cultural, connectivity and protection) determined through the regional biodiversity workshop are also presented as these are more likely practical options for on-ground implementation. Current approaches to ecosystem restoration and possible amendments for consideration in a changing climate are also discussed.

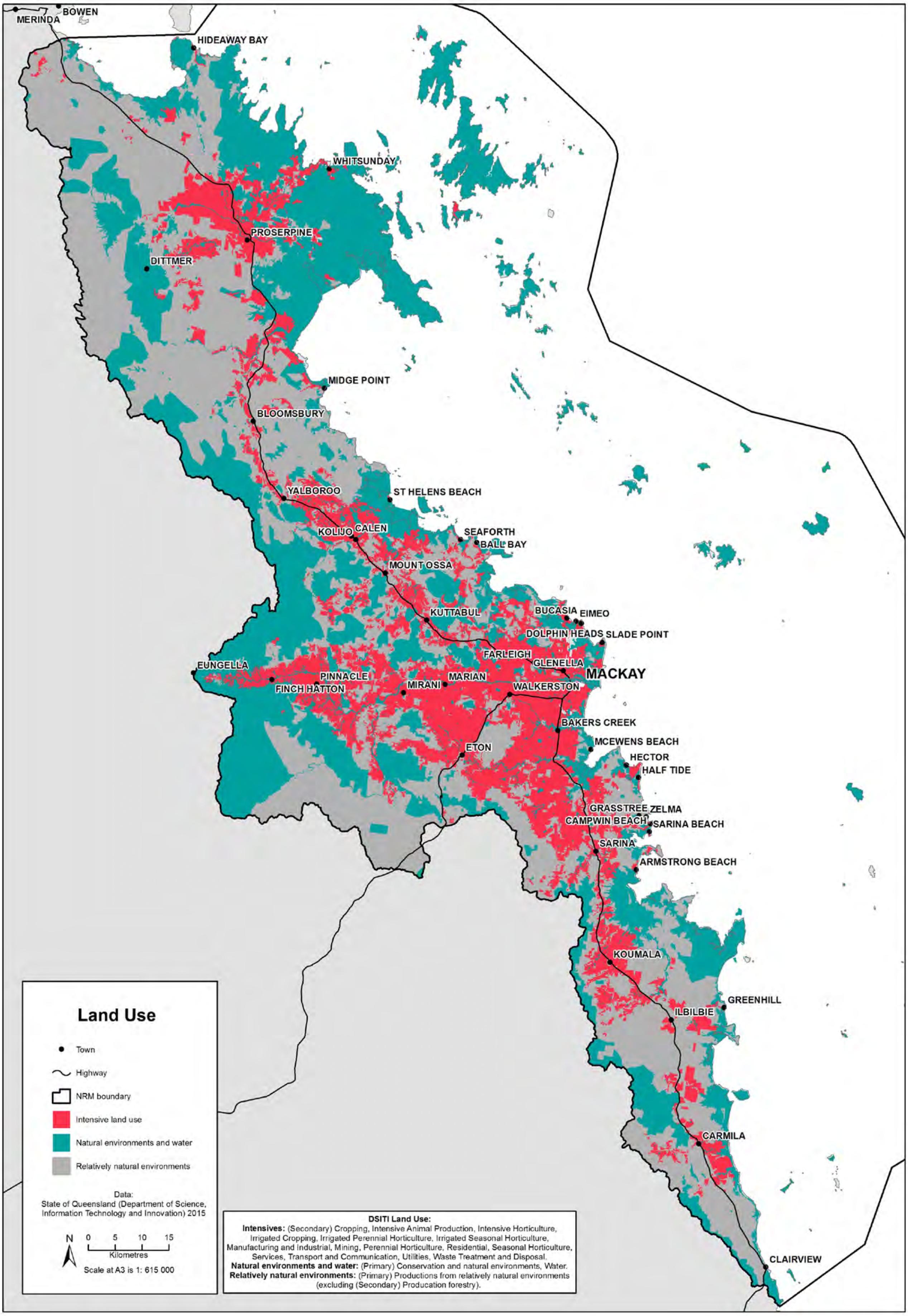
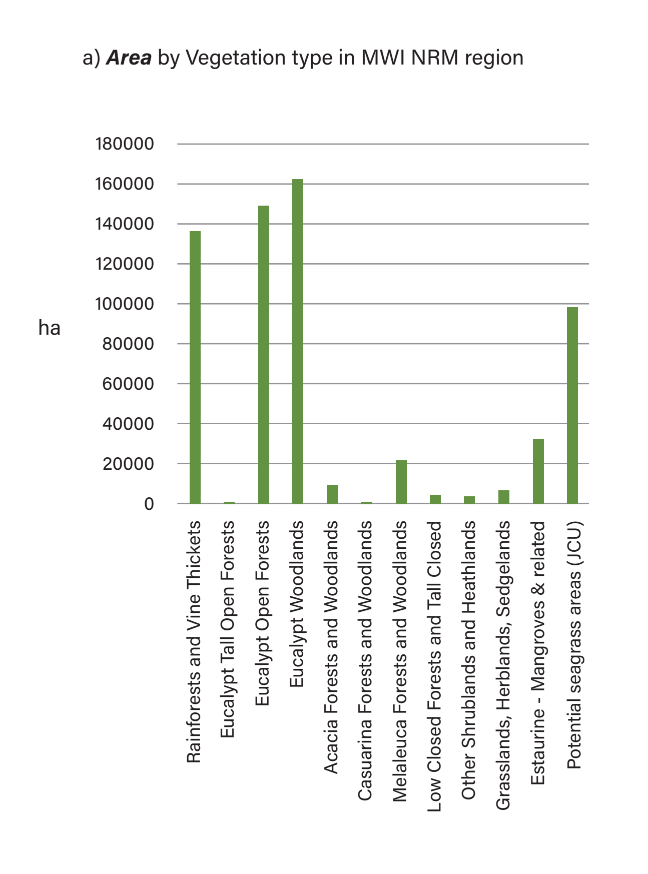


Figure 6.1 *Land use in the MWI NRM region*



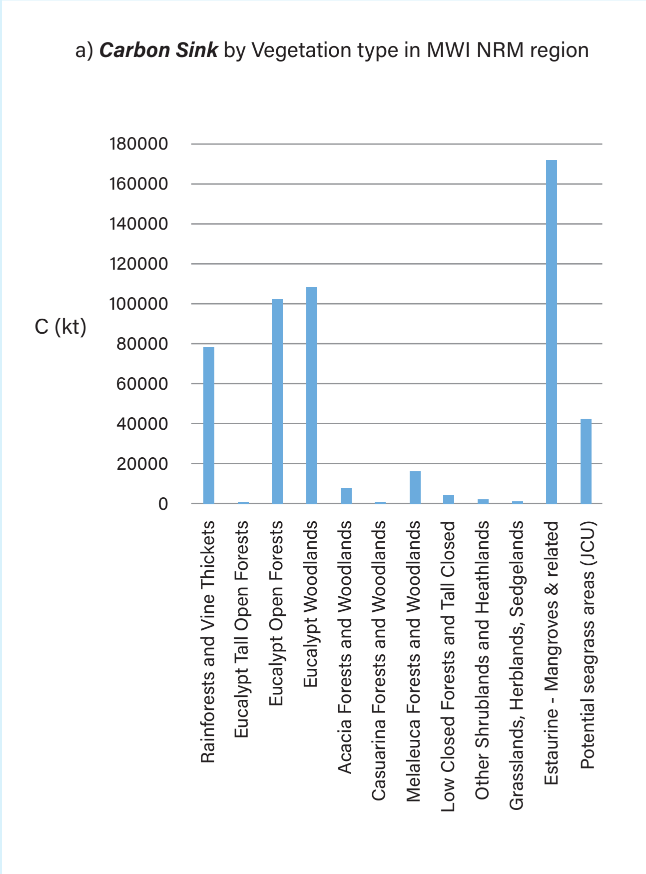


Figure 6.2 *Major vegetation types in the region by a) land area and b) carbon sink- or amount of C stored*

Carbon audit of existing vegetation communities

A stocktake of carbon in vegetation communities in the MWI NRM region was undertaken by RPS (2014) with 2013 land use data using FullCAM. FullCAM is the model used to construct Australia's national greenhouse gas emissions for the land sector and uses the national vegetation classification system; which is at a broader scale than the Queensland Regional Ecosystem Description Database (REDD). Estimates of carbon (C) storage from coastal and marine ecosystems have also been taken from international literature, as FullCAM only considers soil C in mangroves to 30cm in height and does not estimate carbon storage in seagrass communities. The results of this stocktake are shown in Figure 6.2.

Coastal ecosystems provide many services to humanity (cultural significance to Traditional Owners, mitigation of damage from extreme weather events, fish habitat etc.) and also tend to have higher stores of carbon than other terrestrial ecosystems. Tropical rainforests tend to have equal amounts of carbon stored in plants and soil; however wetlands, coastal and marine communities may store up to 10 times more carbon in sediments than in above-ground biomass (Pidgeon 2009). Additionally, carbon stored in marine communities is stored over longer time scales than that in aboveground biomass, as sediments will accrete vertically in response to rising sea levels (McLeod *et al.* 2011). It has also been documented that retention/re-instatement of coastal ecosystems can be more cost effective than using structural approaches from mitigating of damage in extreme events (Mangi *et al.* 2011, Queensland Government 2012).

Landscape-scale priorities for biodiversity protection and connectivity

The Queensland Government's Biodiversity Planning Assessment (BPA) identifies the terrestrial ecological values in a region according to their conservation significance (https://www.qld.gov.au/environment/plants-animals/biodiversity/planning/). Spatial datasets generated from the BPA assessment for the Central Queensland Coast identifies areas of state and regional significance for both terrestrial and aquatic environment. Figure 6.3 shows the results from this assessment, released in 2007 (https://www.qld.gov.au/environment/plants-animals/biodiversity/central-coast/).

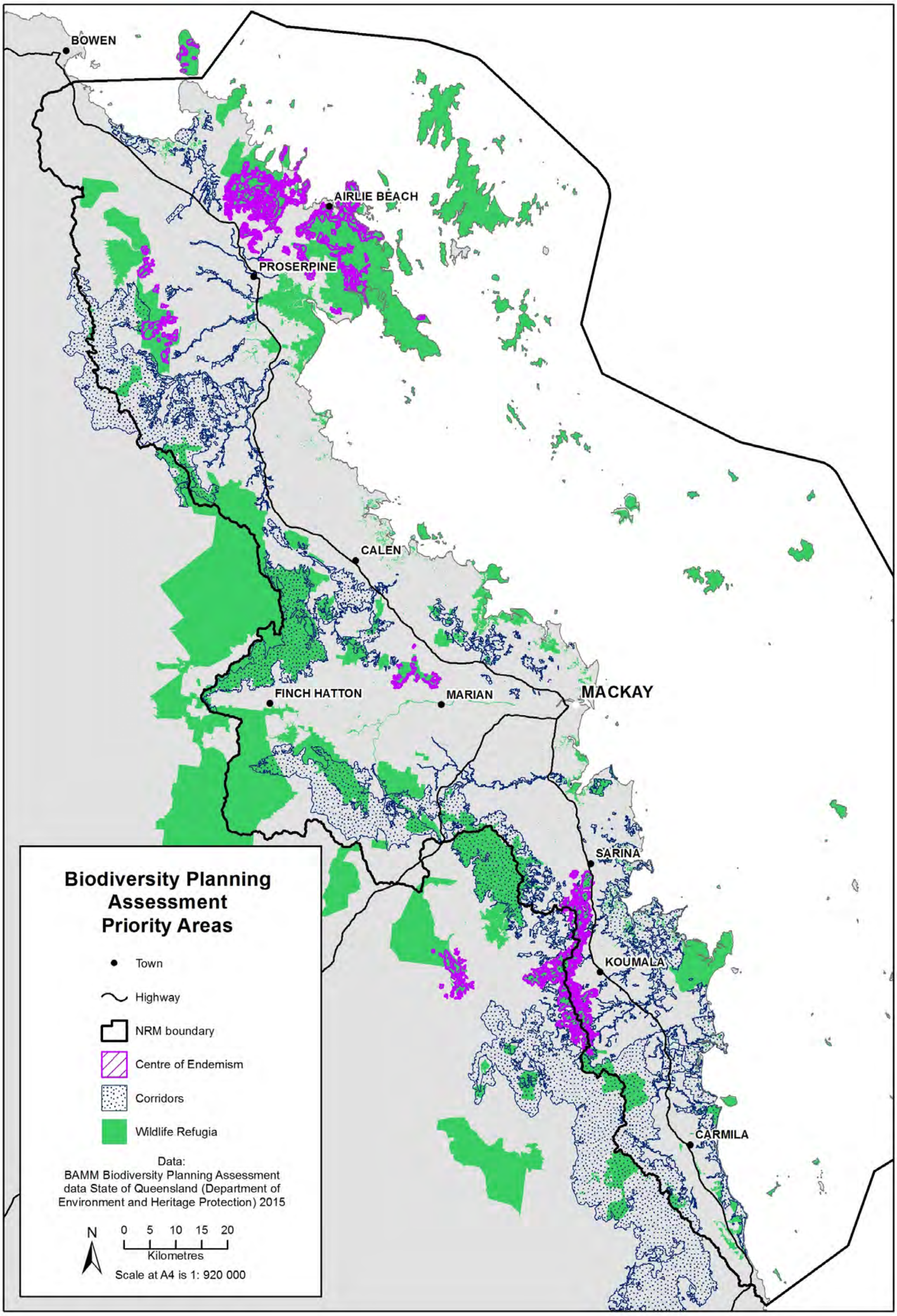


Figure 6.3 *Biodiversity Planning Assessment priorities for endemicity, wildlife refuges and corridors for connectivity.*

Queensland Herbarium have also developed a biodiversity metric (Figure 6.4) using regional ecosystem mapping and other spatial data to prioritise areas in the landscape for native vegetation restoration to benefit both carbon and biodiversity (Butler et al. 2014). The principles used in developing the metric were:

- Prioritise regional ecosystems heavily impacted by past clearing
- Prioritise landscapes heavily impacted by past clearing
- Prioritise habitats of threatened species
- Prioritise areas connected to existing habitat

The resulting map (Figure 6.4) provides an overview of priorities for vegetation restoration within non-remnant areas. Profitable carbon farming, based on native forest regrowth (assisted natural regeneration), is generally more profitable than environmental plantings, primarily because regrowth has lower upfront costs than plantings (Evans et al., 2014; Butler & Halford 2015). To further explore regrowth benefits go to http://environment.ehp.qld.gov.au/regrowth-benefits/.

In general, intensive land uses such as sugarcane cultivation and built-up areas (as shown on Figure 6.1) have very little amounts of high-biodiversity non-remnant regrowth and there is a good proportion of non-remnant regrowth in grazing lands. Encouraging retention, restoration and exploring opportunities for improving landscape connectivity with willing land managers needs to be a priority within existing programs for natural resource management.

The Mackay Whitsunday Isaac Water Quality Improvement Plan 2014-2021 (Folkers et al. 2015) identified waterways in sub-catchments in the NRM region as priorities for protection and maintenance (due to their existing high ecological values) and priorities for system repair works. Priorities for system repair works in waterways are based on that their ecological values are fairly good, water quality is reasonable and the likelihood of improving ecological values would be successful and at the least cost. Figure 6.5 shows the sub-catchments defined by this Water Quality Improvement Plan for protection and maintenance and highest priority for systems repair.

Outputs from the Wet Tropics Cluster research consortium included spatial projection of suitable future climate space for vertebrates in the region based on current distribution records from the Atlas of Living Australia (Reside, unpublished data). Species in the region analysed included 30 frogs, 261 birds, 61 mammals and 85 reptiles, a total of 437 species. Principles in the landscape prioritisation process were to:

- Find areas that complement each other: not just with the most species, but important areas so that all species are included (with endemic and restricted species weighted higher);
- Include future climate change distributions, connectivity and species dispersal.
- Incorporate several future time steps (2055 and 2085) priority areas for species and the areas that overlap with each
- Find the optimal solution for current and future biodiversity

(Reside, unpublished data)

Further work undertaken by Reside (unpublished data) has also indicated that there is only a marginal trade-off with carbon when biodiversity is prioritised.

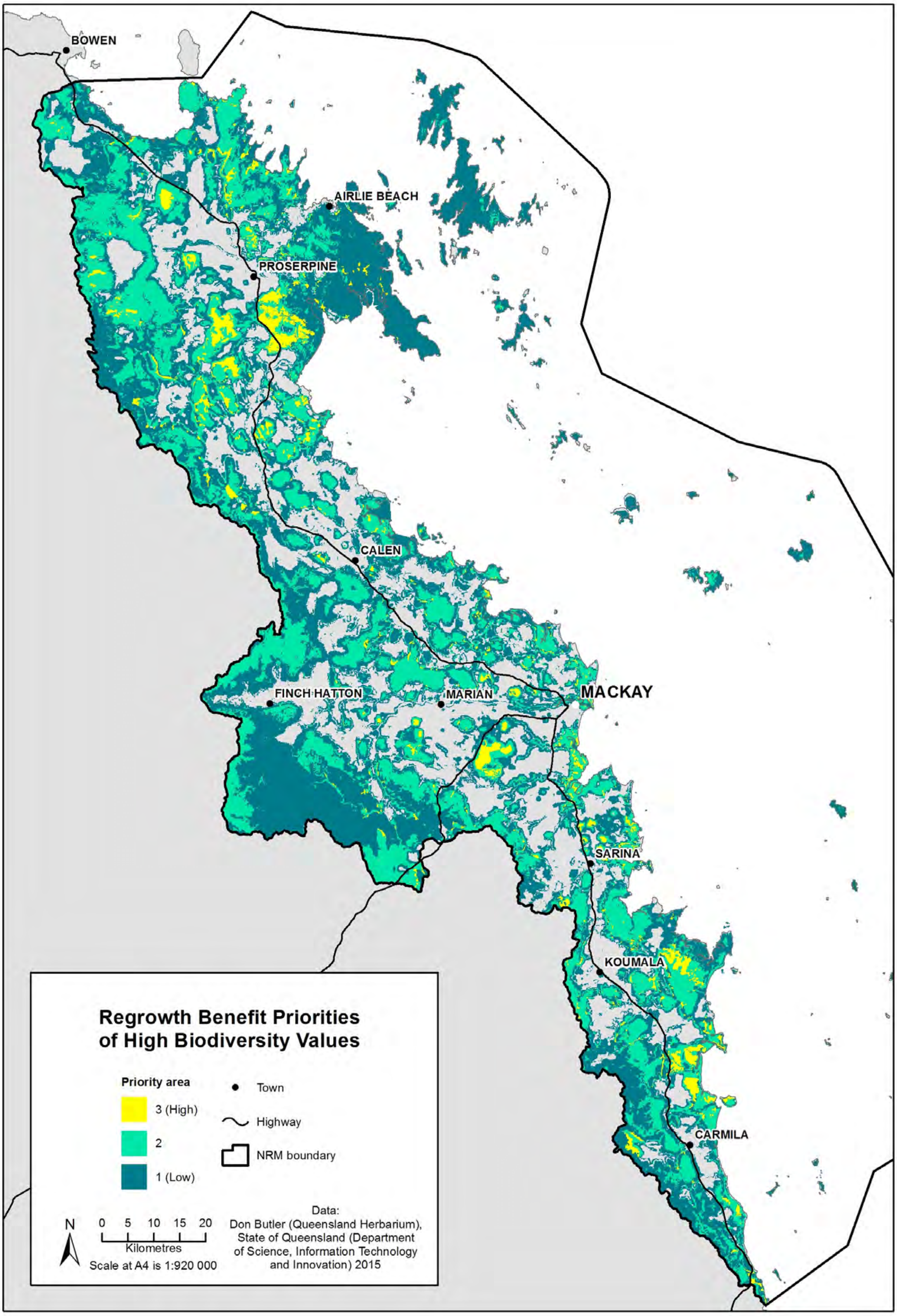


Figure 6.4 *Non remnant regrowth of high biodiversity value in the region*

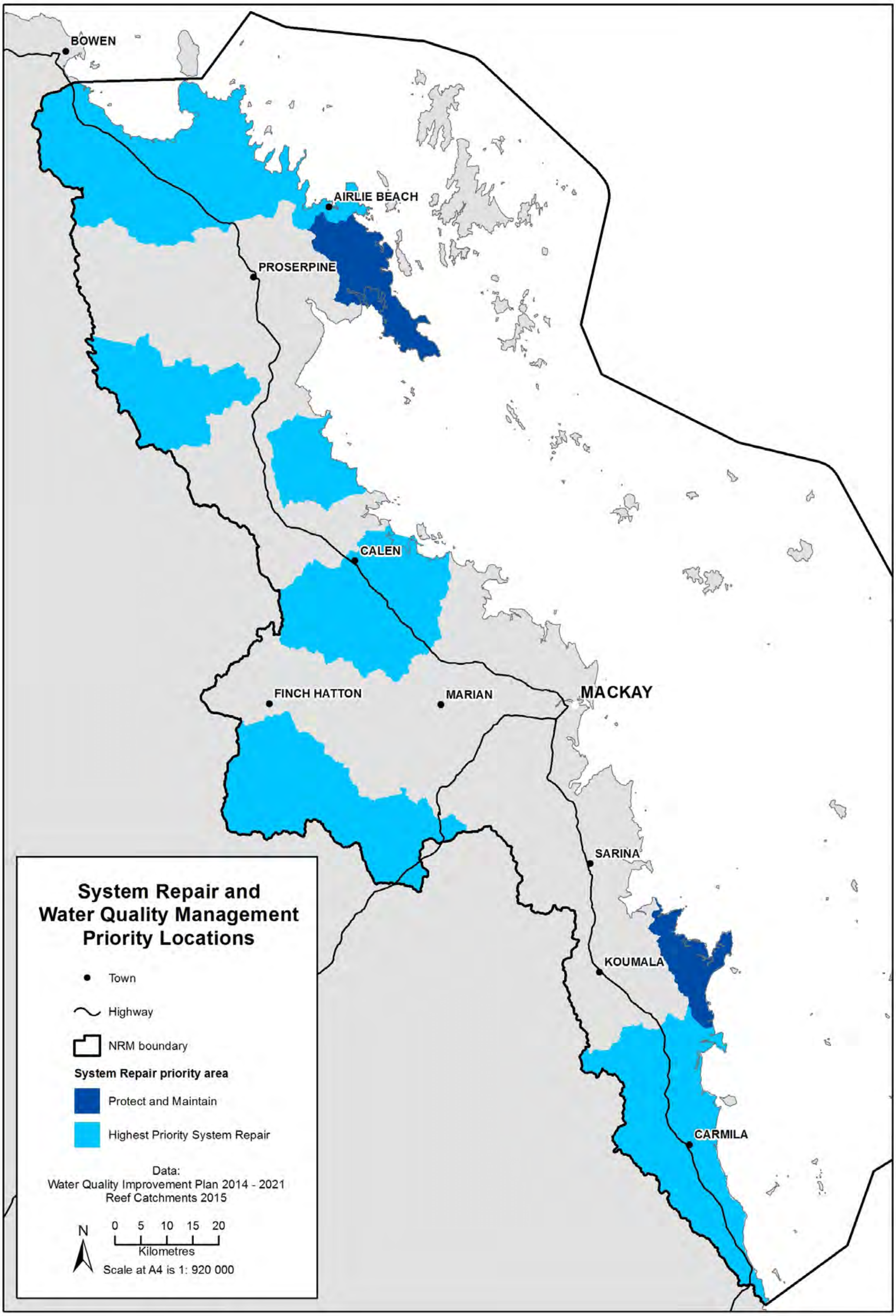


Figure 6.5 *Priority sub-catchments in the MWI NRM region for protection and maintenance and high priority system repair works for water quality improvement (Folkers et al. 2015)*

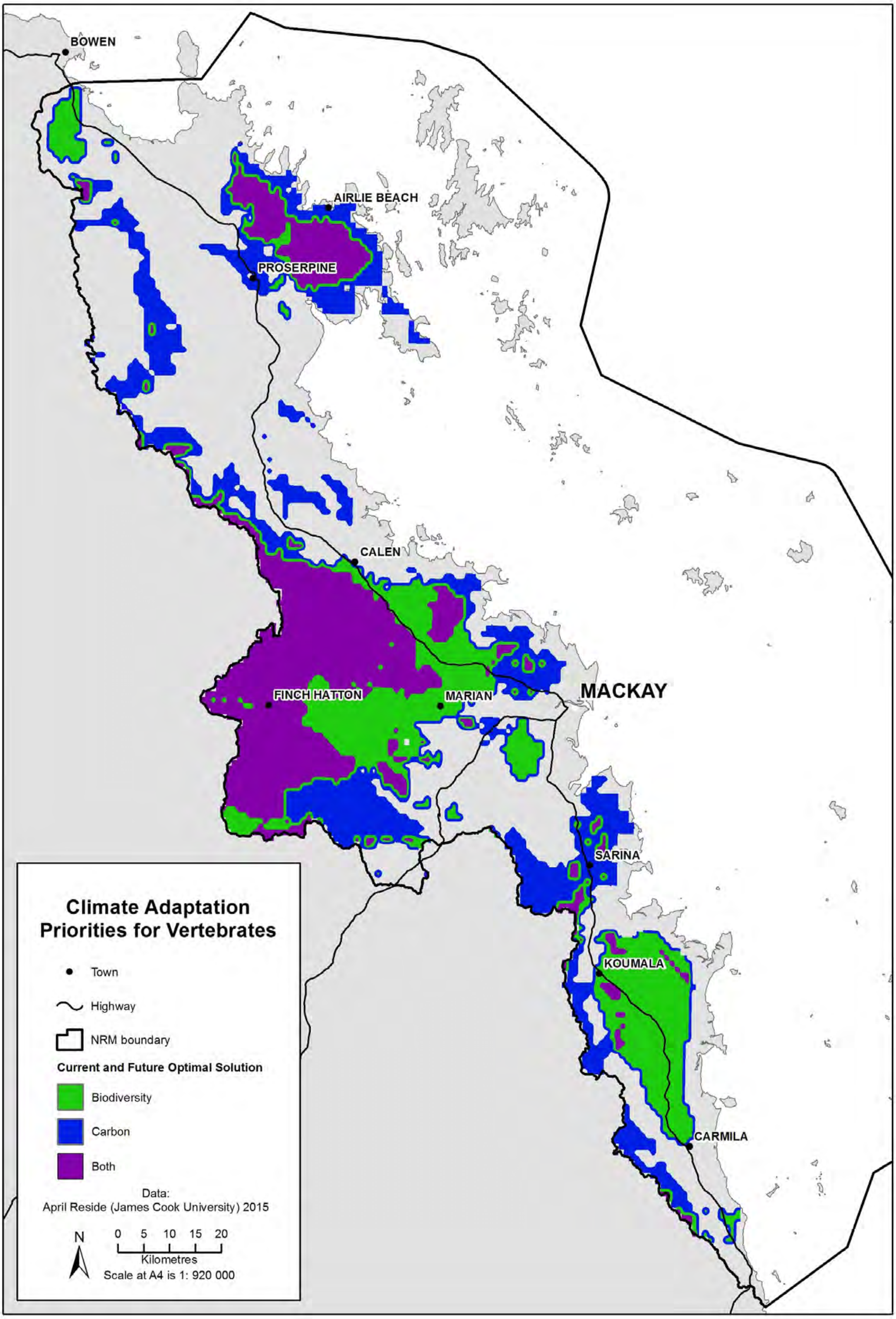


Figure 6.6 *Optimal solutions for current and future biodiversity, and carbon and both carbon and biodiversity in the MWI NRM region (Source: Reside, unpublished data)*

This work, however, did not consider existing land use or tenure within the region. There is 22% of areas within the biodiversity and carbon layers that overlap within intensive land uses; however protected areas overlap with 61% for current and future optimal biodiversity and carbon outcomes and remnant vegetation 61%. This indicates that although there is fragmentation of habitats within the MWI NRM region; focussed protection and restoration works through the region are likely to provide the necessary landscape connectivity to assist in biodiversity adaptation to climate change.

Another result of this work is that a number of vertebrate species are projected to lose suitable climate space completely in the MWI region; these are listed in Table 6.1. These species however, may have suitable climate space in other areas.

Table 6.1 *Species losing all suitable climate space in the future within the MWI NRM region (Reside, unpublished data) and their current conservation status*

Vertebrate Type	Species	Conservation status
Frogs	New Holland Frog (Cyclorana novaehollandiae)	Least concern
	Revealed Frog (Litoria revelata)	Near-threatened (Qld)
	Great Barred Frog (Mixophyes fasciolatus)	Least concern (IUCN)
	Large Toadlet (Pseudophryne major)	Least concern (IUCN)
	Dusky Toadlet (Uperoleia fusca)	Least concern (IUCN)
	Littlejohn's Toadlet (Uperoleia littlejohni)	Least concern (IUCN)
Birds	Chestnut teal (Anas (Nettion) castanea)	Least concern (IUCN)
	Western gerygone (Gerygone fusca)	Least concern (IUCN)
	Wonga pigeon (Leucosarcia melanoleuca)	Least concern (IUCN)
	Rose robin (Petroica (Erythrodryas) rosea)	Least concern (IUCN)
	Striped honeyeater (Plectorhyncha lanceolata)	Least concern (IUCN)
Mammals	Wallaroo (Macropus robustus)	Least concern (IUCN)
Reptiles	Elegant Snake-eyed Skink (Cryptoblepharus pulcher)	Not of concern
	Dark bar-sided skink (Eulamprus martini)	Not of concern
	Pale-headed snake (Hoplocephalus bitorquatus)	Not of concern (Qld)
	Stephens' banded snake (Hoplocephalus stephensii)	Changed from rare to least concern 2009 (Qld)
	Northern velvet gecko (Oedura castelnaui)	Not of concern
	Eastern bearded dragon (Pogona barbata)	Not of concern
	Brown-snouted blind snake (Ramphotyphlops wiedii)	Not of concern
	Wedge-snouted shadeskink (Saproscincus czechurai)	Not of concern

Despite some species endemic to the region losing suitable climate space, the region is highly likely to be suitable for other species endemic to neighbouring regions. To date, there has been no research undertaken as to the likely movement of species to move into the MWI NRM region with the changing climate or suitable climate space outside of this region for species listed in Table 6.1.

Work on endemic birds indicates that there is likely to be movement between the MWI region and other areas such as Cape York and the Wet Tropics (Anderson et al., 2012).

Landscape priorities for protection and restoration

A union was conducted using the landscape scale spatial data relating to biodiversity described previously (Figures 6.3, 6.4, 6.5 and 6.6). Each layer of the spatial datasets was given a rank. The regrowth benefits matrix (Figure 6.5) medium to high values were given rankings of 3 to 1 (high to low). The climate adaptation modelling (Figure 6.6) was ranked: carbon = 1; biodiversity = 2; areas of both carbon and biodiversity = 3. The system repair priority locations (Figure 6.5) were ranked: Protect and maintain = 2, highest priority system repair = 1. The BAMM (Figure 6.3) layers of Corridors, Endemicity and Refugia were given a total rank of 1. The union of these four layers provided an indication of areas of priority in the landscape. Areas of protection and restoration were delineated by the use of the Regional Ecosystem dataset: where the areas of priority intersected with non-remnant areas = priority for restoration. Where the areas of priority intersected with remnant areas = priority for protection. This analysis was conducted to prioritise across the landscape areas for protection and restoration with the greatest biodiversity and carbon outcomes using multiple spatial datasets and is shown in Figure 6.7.

As described in Chapter 2 regional stakeholders participated in a biodiversity workshop in September 2015 and were presented with the spatial information relating to non-remnant biodiversity, hazards and results from the climate refugia research. Traditional Owners present on the day also delineated areas of cultural significance. The priorities determined by regional stakeholders (community values) are also shown with the landscape priorities for protection and restoration in Figure 6.7.

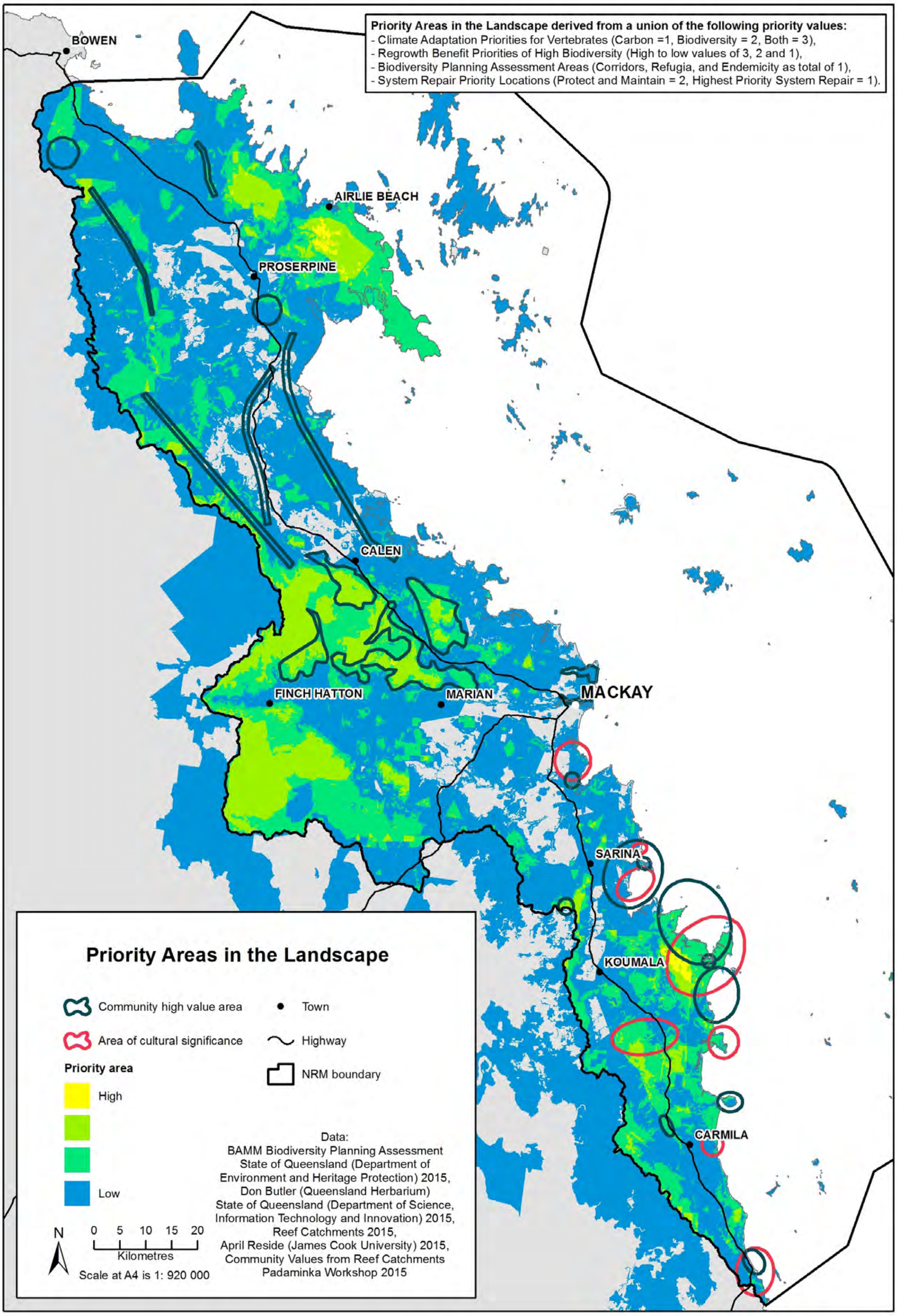


Figure 6.7 *Landscape priorities for protection and restoration and community values (including areas of cultural significance): Note: mapping of cultural values in the region requires additional engagement with TO's*

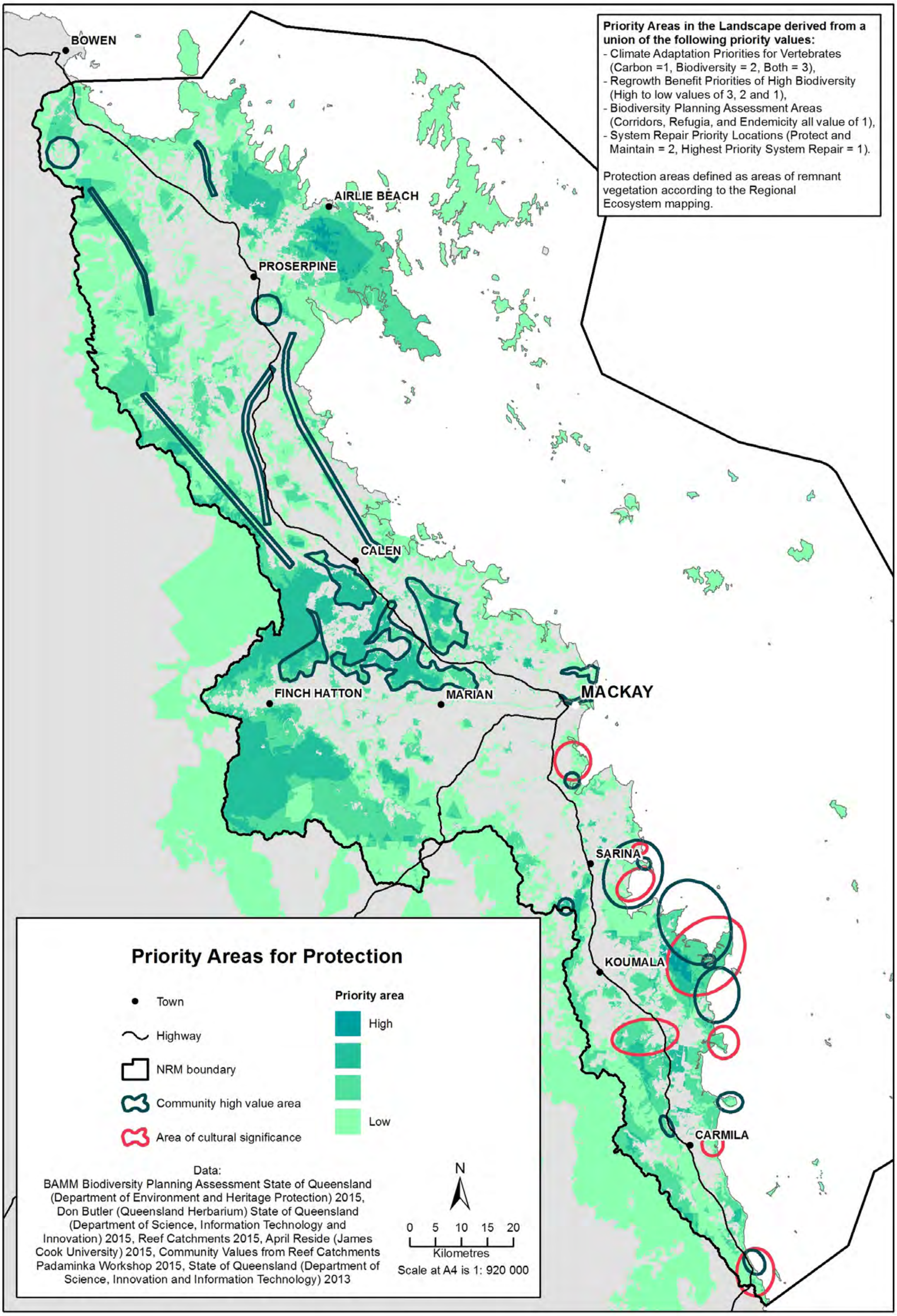


Figure 6.8 *Landscape priorities for protection in a changing climate for the MWI NRM region*

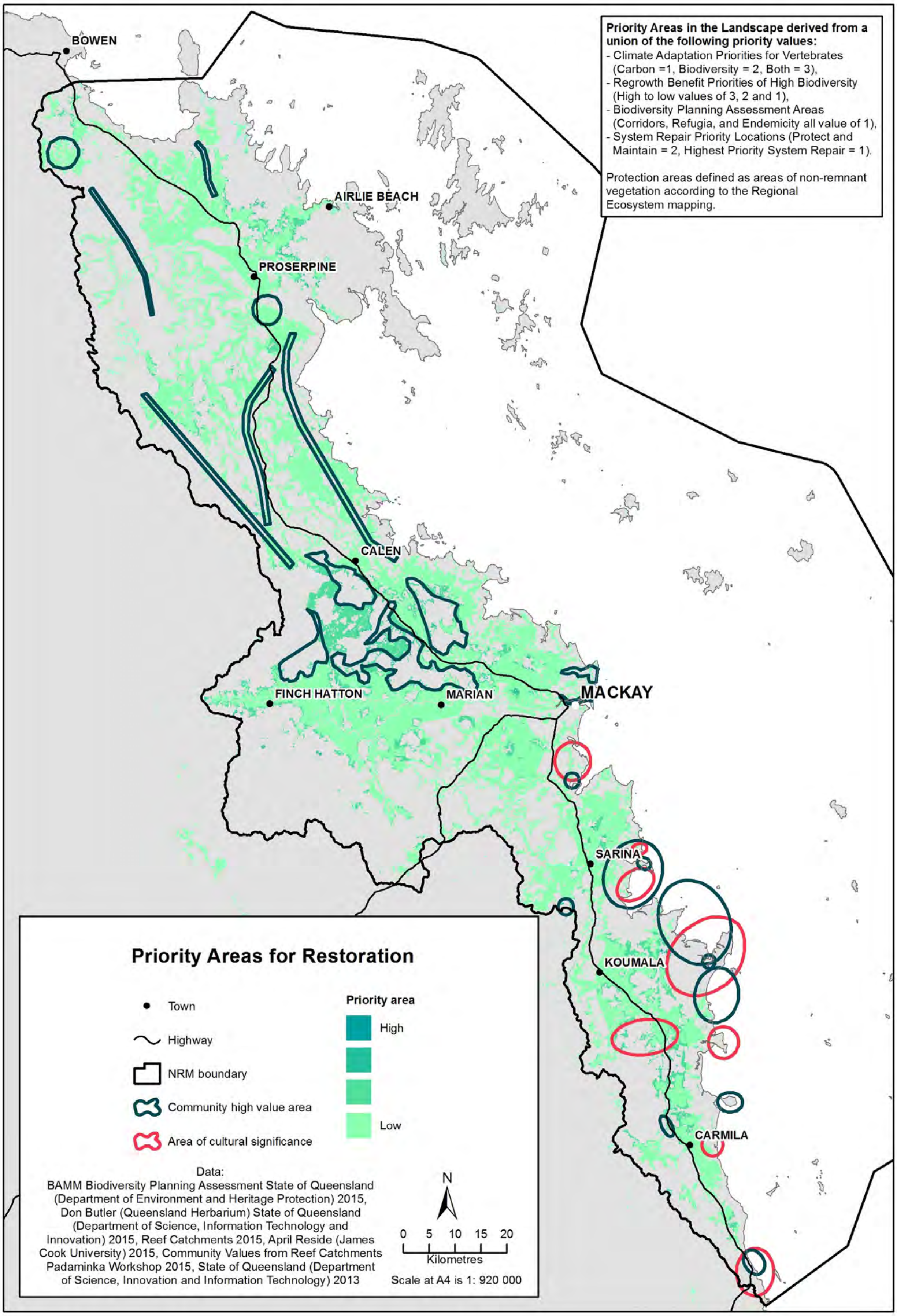


Figure 6.9 *Landscape priorities for restoration in a changing climate for the MWI NRM region*

The overall priorities for protection and restoration in a changing climate are in those that currently have high biodiversity values. This needs to be maintained to support biodiversity to adapt in a changing climate. The priorities for protection are currently around Conway, Dryander, Proserpine State Forest, Eungella National Park, Crediton and Mia Mia State Forest and Cape Palmerston National Park. Management of these areas needs to ensure maintenance of biodiversity values to conserve these values, provide refugia and assist the regions' biodiversity to adapt in a changing climate.

Riparian areas do not correlate highly, likely due to their lack of overlap with existing refuges and the narrow nature of riparian vegetation currently on many rivers and streams within the region. Well-vegetated riparian areas however, are highly important for connectivity and their ability to provide refuge on 'hot days' for fauna. Narrow strips of vegetation may be ineffective and strategies (e.g. carbon/ biodiversity payments) that encourage revegetation to increase the width of riparian vegetation will increase the resilience, integrity and effectiveness. Priority riparian corridors identified through this process include riparian systems within Rocky Dam Creek, St Helens Creek, Murray Creek Management Area and Repulse Creek Catchment. Community priorities for riparian connectivity were the O'Connell, Marion Creek and Gregory River Catchment Management Areas.

Current approaches to ecosystem restoration

Most approaches to ecosystem restoration and revegetation are based on the notion of restoring habitats that are thought to have occurred in the area at the time of European settlement (i.e. regional ecosystems). However, in the context of the various and unpredictable responses of plants and animals to climate change, attempts to maintain or restore ecosystems using the pre-European reference point are likely to fail. To develop understanding of suitable approaches to restoration, it will be important to maintain records about the methods used in restoration projects (including species selection and seed source), together with associated outcomes (e.g., whether or not planted species are surviving and whether or not plant and animal species are using the areas). Another potential shift in 'traditional' ecological restoration practice relates to the source ('provenance') of seed for plants used in restoration. It has 'traditionally' been assumed that the use of locally sourced seeds would yield plants that are best adapted to local conditions, however, with the changing climate, using seeds sourced from areas that currently have the climatic conditions that are projected for a given site may improve the longer-term success of restoration efforts.

SUMMARY

Spatial priorities for protection and restoration have been presented in this Chapter. The integrity of existing areas of high biodiversity needs to be maintained and improved where possible (through removal of existing threatening processes) to assist biodiversity to adapt in a changing climate. Restoring connectivity throughout the landscape will assist the ability of those animals that require cover to move to climatic refuges throughout the landscape. On-ground implementation will be achieved only with co-operation of land managers in all areas; particularly those riparian corridors identified that are within intensive land uses. Narrow riparian corridors (e.g. revegetation only to the high bank) may be ineffective in a changing climate due to their narrow nature, lack of sufficient internal integrity and resulting disturbance that is caused by extreme events. Current approaches to restoration also need to be re-assessed by practitioners working in these areas.

CHAPTER 7

Strategies for Action

The policy context defining regional strategies for climate mitigation and adaptation

In mid-December 2015, 196 nations, including Australia, signed the Paris Agreement which will follow on from the Kyoto Protocol when it ends in 2020 (http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf). The agreement commits nations to keep the global warming level to below 2°C with an aim of 1.5°C and calls for global emissions to peak as soon as possible.

In order to honour theses agreements the MWI region region needs to play its role in reducing emissions. Adelaide is striving to be the worlds first carbon neutral city with a target for becoming carbon neutral by 2025 (Adelaide City Council 2015). The Queensland Government is pushing ahead with its 50 per cent renewable energy target by 2030. Reef Catchments would like to see committment made in the Mackay, Whitsunday and Isaac region to aim for future carbon neutrality.

Existing plans that include the MWI Region

The Mackay Whitsunday and Isaac Region encompasses a large stretch of the Great Barrier Reef Marine park just off shore and surrounding our islands. It is important that we consider actions and recommendations provided in reports produced by other agencies to guide the way we manage our region to ensure overall reef health targets are met and that our region is exceeding its required contribution to securing a healthy reef into the future. Guiding documents include;

- The Great Barrier Reef Climate Change Action plan 2012-2017 (GBRMPA 2012) provides actions for climate change adaptation for the Great Barrier Reef.
- The Great Barrier Reef Water Science Taskforce Final Report (Queensland Governement 2016) highlights specific actions to build resilience of the reef by reducing all other stressors as much as possible, including poor water quality, crown-of-thorns starfish and other direct impacts like fishing.
- The Reef 2050 Long-Term Sustainability Plan (Commonwealth of Australia 2015)

Reef Catchments workshopped a series of strategies for the region during multi-stakeholder engagement processes. This engagement together with guidance from other documents relevant to our region have formed the basis for strategies summarised and collated in Table 7.1. Strategies have been grouped based on similarities in the issues they address. These strategies provide a starting point for prioritising actions that address priority issues identified with this informed group. Strategies were identified to take advantage of opportunities and minimise risks. The potential for trade-offs between sectors was considered, though this would need to be negotiated on an ongoing basis. Across all workshops, a strong theme emerged of empowering the community to understand issues and motivate action. In addition to the strategies identified here, State Government policy was recognised as having a critical role to play, for example in ensuring that infrastructure serves communities before private interests, and in facilitating localisation. The Aboriginal Cultural Heritage Act 2003 is also important legislation for Traditonal Owner's as it gives them legal grounds to advocate and limit action that can potentially damage their sites. Strategies listed ideally will be considered by all stakeholders in the region and relevant strategies incorporated into their mitigation and adaptation planning policies.

Table 7.1 *Strategies for Adaption to Climate Change in the MWI Region.*

Strategy Number	Strategies
S1	**Collaboration: Facilitate collaboration across sectors:** ▪ Foster two-way sharing of knowledge and information between government, industries and communities; knowledge brokering ▪ Use local knowledge, as well as science to inform planning ▪ Facilitate work to design a realistic climate vision for the region including mitigation targets for a carbon neutral future
S2	**Strategic Planning: Embed climate change and future sustainability into planning:** ▪ Develop policy that is strategic, longer-term focused and prioritises public good ▪ Improve ecological connectivity and plan for landward migration of coastal ecosystems ▪ Protect good agricultural land for food production ▪ Improve transport cohesion and plan transport systems for a lower carbon future ▪ Secure water resources and plan upgrades of infrastructure for future predicted climates and populations ▪ Consider coastal protect and retreat options as a region to ensure environmental, economic and social values of coastlines are maintained ▪ Review adaptation offset schemes and avoid maladaptation
S3	**Economic Sustainability: Assist industries to adapt** ▪ Promote industry diversification and improve viability of existing industries ▪ Identify regional competitive advantage, innovation and reduce dependence on single industries i.e. the mining industry ▪ Promote carbon market opportunities ▪ Explore renewable energy opportunities in the region (i.e. cogeneration plants, wave and tidal energy) ▪ Assist in carbon mitigation planning and promote sustainable practice (e.g. low carbon sugar) ▪ Plan migration/adaptation of high risk, high economic value areas such as iconic tourism areas ▪ Reduce impacts of industries on environment (work with industries to improve water quality, minimise waste, use alternative power, source locally), monitor and improve
S4	**Ecosystem Health and Biodiversity: Build resiliance and foster adaptation** ▪ Protect significant flora, fauna and ecosystems ▪ Facilitate coastal ecosystem landward transition ▪ Establish vegetation corridors between existing protected areas – coastal & riparian ▪ Maintain updated information stream on research and monitoring projects and outcomes ▪ Secure water and land for the environment ▪ Ensure adapation offset schemes are adequate and that regional wide adaptation is well planned to protect an acceptable level of ecosystems for species survival (i.e. enough beaches are protected and allowed to retreat (without rock walls etc) to ensure turtle nesting is not significantly impeded)
S5	**Cultural Heritage: Greater, more meaningful involvement of Indigenous people** ▪ Improved sense of belonging by encouraging acknowledgement of TO's across all sectors ▪ TO's involved in planning how they wish to be engaged ▪ Greater consultation on land-use decisions and improved incorporation of Indigenous knowledge into land, water and sea management, in particular burning practice, seagrass and water quality monitoring
S6	**Community Education:** ▪ Effective engagement with entire community - including schools, seniors, Traditional Owners (TO's), sporting and other community groups ▪ Develop sense of ownership to motivate and empower action and change ▪ Develop sense of responsibility for choices and promote community leadership ▪ Improve community capacity to respond to the predicted changes in climate
S7	**Health & Wellbeing** ▪ Facilitate a healthy environment for the health of our community
S8	**Disaster Risk Management** ▪ Reduce risk of disasters, improve resilience to disasters and plan for recovery

Strategies for Reef Catchments

Four key actions were identified during the workshop in relation to incorporating climate adaptation into Reef Catchments' plans and processes:

Build capacity within Reef Catchments staff to identify climate change impacts and flow-on effects

Increase awareness within Reef Catchments of Stream 2 and other scientific information and integrate this into work programs across the organisation. This could be facilitated through a co-ordinated and consolidated process such as regular meetings and periodic workshops.

Develop land use plans with climate change scenarios

There was support for undertaking ecosystem services mapping of the region, likely social responses and incorporating climate impacts in a risk-management framework (e.g. how climate change impacts affect ecosystem service values; whether to focus on short- to medium-term projects such as coastal restoration considering longer-term projections for climate change impacts). Develop accompanying information for plans e.g. fact sheets describing implications for ecosystem functionality.

Target work to high-levels within NRM stakeholder community

It was recognised that Reef Catchments' work will be more likely to influence transformational change through the promotion of awareness of the risks and opportunities associated with climate change at high levels of governance within the MWI NRM stakeholder community. This would include CEOs, managers and team leaders in Local and State Government, as well as rural and other industry sector leaders. Again, it was considered important to conduct dialogue in risk-management framework

Continue to work with broader NRM stakeholder community, including grassroots

There was strong support for continuing Reef Catchments' engagement activities with a diverse stakeholder community. It was considered important to integrate social, cultural and economic objectives, as well as environmental. It was recognised that working groups arising from this engagement have an important operational focus, but will not be likely to engender longer-term transformational change. This may be an important means of measuring impacts of adaptation measures.

Actions required to Achieve Strategies

Priorities for Carbon and Biodiversity

In the context of the NRM Planning principles provided by the Federal Government (see Chapter 1), two main priorities have been determined in this Plan with priority areas for biodiversity and carbon outcomes identified spatially in Chapter 6. These are:

- Maintain and enhance existing terrestrial and marine carbon stores in the region
- Improve/ reinstate connectivity in the landscape to improve landscape resilience and increased access to climate refugia.

Specific actions include:

- Increasing Traditional Owner involvement in planning, monitoring and management
- Increase nature refuges and protected areas
- Encouraging use of fire management regimes appropriate to ecosystem type that maintain biodiversity
- Maintaining/ increasing management, monitoring and control of invasive species including upskilling in identification of sleeper weeds
- Promoting revegetation/ regeneration (by removing threatening processes) to increase integrity of existing carbon stores
- Effectiveness of revegetation efforts. Lack of monitoring of effectiveness of decades of revegetation; including animals using these areas for refugia is urgently required
- Incorporating value of ecosystem services (e.g., buffering of coastal settlements from extreme events, carbon sequestration, protection of water quality) in development of planning schemes and assessment of development proposals.

Stakeholders acknowledge the uncertainty around resourcing for implementation of the actions and strategies they have identified and have expressed the intention to work to incorporate the recommendations contained in this plan into the delivery of existing programs (e.g., biodiversity/ natural resource management/ sustainable agriculture outcomes) and planning processes.

Meaningful stakeholder engagement

Ongoing, meaningful engagement with regional stakeholders will be crucial to the implementation of mitigation and adaptations action in the region. These will need to be regionally-relevant and cross-sectoral so will depend on the active involvement of all sectors of the community. Importantly, community involvement is essential to developing adaptation pathways that move the region in the direction of the aspirations held by the community. Adaptive change is inevitable as climate change impacts continue and intensify, but it is likely that actions and strategies devised by local community stakeholders will reflect more of their local aspirations than those imposed from outside the region or without meaningful community input.

During the process of developing this Plan stakeholders expressed a sense that stakeholder consultation is often perceived as 'token' and that social, cultural and environmental values are not given equal weight as economic considerations. Multi-stakeholder processes focused on sharing of issues and perspectives between the various stakeholder groups to encourage better understanding across sectors. Development of collaborative strategies and actions were also focussed on ensuring minimal trade-offs in aspects of sustainability (e.g. economic growth did not further impact on social displacement or sustainable resource use). A recurring strategy from the workshop processes was the delivery of an annual multi-stakeholder event to further share information, discuss progress in delivering actions/ strategies and re-prioritise actions for annual delivery.

There is clearly an important role for Reef Catchments in facilitating stakeholder engagement and interaction and also in brokering the two-way exchange of knowledge and information between researchers, industries, Local Government, other key stakeholders and the broader community.

Knowledge Gaps

There are many gaps in knowledge about how climate change may impact on the regions' sustainability. Notably, off-shore islands have not been included in this Plan but their biodiversity and cultural values cannot be underestimated. The offshore islands and marine biodiversity in the MWI NRM region represent the Outstanding Universal Values of the Great Barrier Reef area offshore of this region, and will be heavily impacted by climate change. They can also act as experimental sites to monitor climate change impacts on biodiversity and the built environment and how to adjust to them.

Implementation of robust, co-ordinated monitoring will make a major contribution to understanding the actual (versus projected) changes experienced on-the-ground, the impacts, as well as the outcomes of changed practices or adaptation actions. Other key knowledge gaps that have been identified during the development of this Plan include:

- Improved collaboration in planning, implementation and knowledge sharing of rehabilitation, monitoring, results and ongoing development of adaptive management strategies across regional NGO's, TO's and government

- Work with TO's to spatially identify areas of cultural significance and develop strategies for protecting from climate change impacts, co-management and access

- Develop spatial layers for islands in the region that identify hazards and vulnerabilities

- Facilitating the coastal ecosystem transition; examining impacts and adaptive strategies for the false water rat and accelerating inward migration of mangroves

- Research and implementation is required to ensure future provision of turtle nesting habitat and mechanisms to ensure temperature increases do not favour reproduction of one sex.

Table 7.2 focuses on the actions required as a result of the vulnerability assessment that has been carried out in this document. This action plan focuses primarily on Natural Resources however some actions cross over into economic, community and other areas that are intrinsically linked to conservation of these environment into the future. This action plan however does not comprehensively cover all the adaptation actions required to prepare and reduce risks to all other aspects of the region (e.g.. health and emergency services, infrastructure, public services etc.).

Table 7.2 *provides prioritised actions that were identified during regional engagement processes and required to meet targets under other plans encompassing the Region. Priorities were assessed within a risk management framework. Time frames were not systematically assessed in detail but are considered indicative of the likely time-scale required to implement each action once commenced. Lead stakeholder responsible was assigned based on stakeholder perspectives without formal agreement of these stakeholders.*

Action			Lead Stakeholder	Sustainability Principle Addressed	Priority	Action Achieved
S1 Collaboration						
S1 A1	▪	Formation and delivery of a regular (at least annual) multi-stakeholder forum (climate working group) to assist local government, industry and other stakeholders to implement required strategies to mitigate, build resilience and adapt to climate change. This working group should develop a climate vision and set targets for achieving outcomes (including carbon neutrality), be influential and informative. Sectorial working groups should be formed to progress specific initiatives (e.g. biodiversity/TO collaboration/carbon markets). Funding opportunities should be discussed to ensure on ground actions for adaptation and carbon mitigation are achieved. Monitoring programs to measure achievement of actions need to be put into place	Reef Catchments	All	High	1-2 years
S1 A2	▪	Develop a central database of scientific work being carried out in the region and provide access to key information e.g. vegetation mapping	Local Government, Reef Catchments	Environment	High	1-2 years
S1 A3	▪	Put in place measures to address knowledge gaps that are limiting response to climate change. Gaps should be prioritised and discussed at the forum.	Reef Catchments	Environment	High	1-2 years
S1 A4	▪	Update the action plan regularly	Reef Catchments	All	High	3-4 years
S2 Strategic Planning						
S2 A1	▪	Strengthen coastal planning laws based on the best available science, making allowance for expected sea level rise, protecting ecologically important areas such as future biodiversity refugia and wetlands and restricting development in high-hazard greenfield areas	Local and State Government	All	High	1-2 years
S2 A2	▪	Consider protect and retreat options for coastal communities through scientific assessment and a participatory community consultation process. Assessment to value environmental, social and economic uses of the coastal areas in the region. Consider the minimal area of each coastal ecosystem needed to maintain environmental services required (e.g.. fish stocks, carbon storage (high in mangroves), provision of access to recreational areas, provision of turtle nesting beaches etc.). Determine a way to protect land that is likely to be used for future retreat of ecosystems such as mangroves. Review compensation in changing land use rights to prohibit development in high-hazard greenfield areas.	Reef Catchments, Local and State Government	All	High	1-2 years
S2 A3	▪	Incorporate future predicted extreme events into local planning scheme (current and future), including fire, sea level rise and storm tide. Determine planning horizon (eg. to 2090) and model to use in region (eg. RCP8.5).	Local and State Government	All	High	1-2 years
S2 A4	▪	Develop land use plans (ecosystem services mapping) highlighting good agricultural land availability under future climate projections. Work with landholders and industry to promote Best Management Practices to reduce land based run off including where necessary retirement of land which is frequently inundated	Reef Catchments, Industry	All	High	1-2 years

S2 A5	▪	Provide adaptation Information for existing buildings to enable options to be considered	Local and State Government	Economic Social Environment	High	3-4 years
S2 A6	▪	Avoid, mitigate or offset impacts on ecosystems (especially coastal due to their high vulnerability) to restore resilience and ecosystem health. Ensure adaptation offset schemes are adequate and that regional wide adaptation is well planned to protect an acceptable level of ecosystems for species survival (i.e. enough beaches are protected and allowed to retreat (without rock walls etc.) to ensure turtle nesting is not significantly impeded).	Local and State Government, Reef Catchments	Environment	High	1-2 years
S2 A7	▪	Consider implications of seawater intrusion on infrastructure (corrosion rates on pipework) and plan required works. Assess low lying water treatment plants, sewerage and other waste facilities (existing and planned) to manage for predicted flood risks and to avoid contamination.	Local Governments	Economic Social Environment	High	3-4 years
S2 A8	▪	Investigate feasible/sustainable options for water storage and supply in a changing climate. Assess existing dams to ensure they are capable of withstanding increased intensity of rainfall events to ensure water storage capacity maintained and to reduce downstream flooding risk. Increase adoption of leading practice in the management of point source water affecting the Reef. Ensure ecologically sustainable regulation of water extraction	State and Local Governments	Economic Social Environment	High	3-4 years
S2 A9	▪	Improve efficiencies to reduce requirement for freshwater (e.g. Change of crop types, industrial changes, water recycling, reduce evaporation of dams and storage facilities (shading/covers and use of vegetation), urban water saving programs)	Industry associations, private sector and Local Government.	Economic Social Environment	High	1-2 years
S3 Economic Sustainability						
S3 A1	▪	Plan regional diversification of industries and secure future local food production	Industry associations	Economic Social	High	3-4 years
S3 A2	▪	Investigate Government support for transition to sustainable industries. Investigate funding sources or start-up capital for alternative industries	State and Local Governments, Regional Economic Development, Industry Associations	Economic Social	High	3-4 years
S3 A3	▪	Facilitate local markets for local products	Industry associations	Economic Social	High	1-2 years
S3 A5	▪	Consider new green industries including native timber tree production, renewable energy production (bio refineries) including energy from waste and recycling programs. Monitor air pollution to identify local changes and maintain below legislated threshold levels.	Regional Economic Development Corporation, Local Government and Industry	Economic Social Environmental	High	3-4 years
S3 A6	▪	Research and development e.g. new crops, stock breeds and commercial fish species, value adding opportunities, additional products (eg. from sugar cane operations) to suit future predicted climates and utilise less fresh water. Develop demonstration sites and trials for (new) best practices	Reef Catchments and Industry	Economic Social Environmental	High	3-4 years
S3 A7	▪	Develop clear understanding of changes in water availability, quality, storage and reuse implications for industry.	Reef Catchments and Industry	Economic Social Environmental	High	1-2 years
S3 A8	▪	Assist tourism, milling and other industries to prepare for the changes to their industry and become more innovative (i.e. improve sugar mill boiler efficiency) to mitigate climate change. Assist industry to understand and fulfil new market standards as they arise (eg. Bonsucro standard for the sugar industry). Communicate new methods (Emissions Reduction Fund, Verified Carbon Standard) and funding opportunities	Reef Catchments and Industry	Economic Social Environmental	High	3-4 years

S3 A9	▪ Tourism sites on the coasts and reef will need to prepare for likely bleaching and shifting of species. Preservation or intense conservation of suitable icon sites with innovative measures to be investigated.	Tourism groups and Economic Development Boards	Economic Social Environmental	High	3-4 years
S3 A10	▪ Collect baseline fish stock data. Investigate potential changes in breeding cycles of fish and other commercially fished marine life to ensure conservation of species with appropriate management and harvest quotas. Consider species that may move into the area and update legislation to provide early licenses or catch limits for these species.	GBRMPA	Economic Social Environmental	Medium	3-4 years
S3 A11	▪ Review of nutrient management guidelines and legislation with respect to nitrogen-based fertilisers (the use of readily-available nitrogen formulations (such as urea) in areas where waterlogged soils present or are predicted as this will produce the greenhouse gas nitrous oxide).	Industry associations and State Government	Economic Social Environmental	High	1-2 years
S3 A12	▪ Improved participation in carbon markets. Consider options for carbon farming in the region to mitigate emissions and potentially expand economic opportunities. Work with established groups e.g. http://www.cleantechalliance.org/ and create linkages with national/international voluntary carbon markets.	State Government and Reef Catchments	Economic Social Environmental	Medium	3-4 years
S3 A13	▪ Prepare for changed and potentially increased impacts from pests, weeds and diseases. Improve biosecurity in the region. Provide ongoing support to the Mackay Regional Pest Management Group to monitor and lead. Prioritise pest management into areas such as islands (where complete eradication is more achievable), critical seabird, turtle nesting sites or areas of high value for Matters of National Environmental Significance.	Local Government, QPWS, Regional Pest Management Group and Reef Catchments	Economic Social Environmental	High	1-2 years
S3 A15	▪ Monitor groundwater. Plan and manage extraction from groundwater. Limit extraction as required as this compounds seawater intrusion. Buy back water extraction licenses as required to prevent use of groundwater. Consider future requirement for other options to secure enough freshwater for the region (desalination etc.).	State Government	Economic Social Environmental	High	3-4 years
S3 A16	▪ Improve bank stabilisation to reduce erosion and better filter runoff. Refer to map 3.5 for prioritisation of areas requiring works. Implement farm planning to integrate riparian buffers for farming activities. Assist landholders to reduce stock access to waterways and promote effective frontage country management including riparian fencing, offstream watering points and selective seasonal 'crash' grazing. Greater extension to promote better managing of stocking rates and breeding and calving to align with seasonal forecasting. Ensure appropriate vegetation buffers to reduce sediment, nutrient and chemical trespass and improve water quality.	Reef Catchments and Industry Associations	Economic Social Environmental	High	1-2 years
S3 A17	▪ Reduce nutrient and chemical loading in water. As per S3 A16 work to optimise use of pesticides and fertilisers, change type of pesticide or fertiliser and improve bank and in-stream vegetation to absorb nutrients and filter water. Implement strategic chemical application to minimise chemical runoff to waterways (include long range weather forecasting to avoid application prior to forecast rain events, strategic use of knockdown herbicides rather than residuals etc.). Follow objectives in the regional Water Quality Improvement Plan (WQIP).	State Government, Reef Catchments and Industry	Economic Social Environmental	High	1-2 years
S3 A18	▪ Improve quality of storm water from residential areas. Reduce pharmaceutical loading of waste water. ▪ Improve water treatment under higher temperature scenarios.	Local and State Government	Economic Social Environmental	High	3-4 years

S4 Ecosystem Health and Biodiversity					
S4 A1	▪ Implement coastal planning laws based on the best available science (including sea level rise) to ensure recognition and protection of ecologically significant areas (e.g. wetlands), land for future conservation, maintenance of ecosystem services and buffering from climate extremes. Add to the protected area estate.	Federal, State and Local Governments, Reef Catchments	Environment Social Economic	High	4-5 years
S4 A2	▪ Map refugia and plan for the protection of high value climate refugia. Target restoration activity based on current and future conditions. Secure protection for Matters of National Environmental Significance.	Reef Catchments, Local, State and Federal Governments, community conservation groups	Environment	High	1-2 years
S4 A3	▪ Plan and implement a biodiversity corridor or stepping stone program to improve landscape connectivity and promote migration of species. Consider both landward and southern shifts. Preference for combined outcomes (carbon and biodiversity)	State Government, Reef Catchments	Environment	High	3-4 years
S4 A4	▪ Implement on-ground activities to reduce the volume of debris generated in or entering the region, and undertake education and awareness raising activities to minimise the source and occurrence of marine debris	Reef Catchments, Local Government, local community groups	Environment Social Economic	High	1-2 years
S4 A5	▪ Identify and monitor species and habitats vulnerable to crossing resilience thresholds. Consider species or ecosystems that may require active conservation to preserve a high value patch into the future with innovative conservation options (e.g. artificial microclimate simulation options) or through assisted translocation of species or communities. This may be required for ecosystems on the southern boundary of the Wet Tropics Cluster to assist relocation of species over the dry tropics landscape to its next preferred climatic location in the Mackay Whitsunday Isaac Region	Reef Catchments and other Wet Tropics Cluster	Environment	High	3-4 years
S4 A6	▪ Protect remnant and high value regrowth native vegetation (including in riparian zones) Assess potential plants of the future. Adjust revegetation planting lists to suit future climates	Reef Catchments, Local Government and conservation groups.	Environment	High	1-2 years
S4 A7	▪ Improve aquatic habitat and connectivity to promote resilience for native fish communities. Construct fish ladders to increase fish migration. Improve riparian vegetation to reduce the temperature of the water in-stream. Improve wetland condition throughout the region	Reef Catchments, Local and State Government, local community groups	Environment	High	1-2 years
S4 A8	▪ Water for the environment programs instated to ensure natural systems maintain minimum water to function effectively. Assess freshwater and estuarine ecosystems and monitor, manage and plan for future shifts in water salinities	State Government, Reef Catchments	Environment	High	3-4 years
S4 A9	▪ Identify land that is likely to be used for future retreat of ecosystems, such as mangroves, and prepare the area for accepting migrating ecosystems	Reef Catchments, State and Local Government.	Environment Social Economic	High	3-4 years
S4 A10	▪ Implement appropriate fire regimes for best management of regional ecosystems (Reef Catchments, 2013). Reduce fuel loads via weed control and reinstatement of native vegetation.	Reef Catchments and Rural Fire Brigades.	Environment Social Economic	High	3-4 years
S4 A11	▪ Implement monitoring programs to evaluate the effectiveness of on-ground actions.	Reef Catchments	Environment	High	3-4 years

S5 Cultural Heritage					
S5 A1	▪ Create partnerships with TO's and Indigenous people in the region. Document their areas of interest. Identify skills set and desired level of involvement. Recognise TO roles and responsibilities over their country. potentially with assistance from the Traditional Owner Reference Group (TORG)	Reef Catchments, Traditional Owners (TORG) and State Government	Cultural Environment Social	High	1-2 years
S5 A2	▪ Work on strengthening sense of place and connection to country in indigenous people in the region. Involve TO's in planning, management and monitoring of natural resources. Develop co-management arrangements	Reef Catchments, TO's, Landcare, NGO's and Local Government	Cultural Environment	High	1-2 years
S5 A3	▪ Develop links with schools and increase cultural heritage information available. Consider programs for indigenous youth to ensure connection to country with a changing climate. Consider establishing educational cultural centers.	Schools, TO's	Cultural Social	High	1-2 years
S5 A4	▪ Identify and protect cultural heritage - Map, photograph and document information on cultural sites as they are today. Work with Traditional Owners to relocate sites if desired for future preservation. Consider options for new bush food and medicine collection gardens to replace those in areas at risk of flooding	Reef Catchments and TO's	Cultural Environment	High	1-2 years
S5 A5	▪ Build resilience of cultural sites by minimising impacts of development and other land uses on significant cultural sites.	Local Government, Reef Catchments, TO's	Cultural Economic Environmental	High	1-2 years
S6 Community Education					
S6 A1	▪ Professional development for teachers to increase knowledge of climate change and incorporation of up to date NRM and cultural knowledge into school curriculum	State Government	Social Environmental	High	3-4 years
S6 A2	▪ Multi-stakeholder forum, including scientists, to provide educational information and tools to promote successful regional adaptation and mitigation. Increase awareness of importance of coastal vegetation (protection, biodiversity, cultural), adaptation options and the ramifications of maladaptation	State and Local Government, Reef Catchments	Social Environmental	High	1-2 years
S6 A3	▪ Improve the involvement and support of local communities in monitoring of climate change and natural resources. Increase community involvement in protecting and managing natural resources.	GBRMPA and Reef Catchments	Social Environmental	High	3-4 years
S6 A4	▪ Increase awareness of changing 'ideal' of coastal living. Map areas according to insurance cost (surrogate for risk)	Local Government and Reef Catchments	Social Environmental	High	1-2 years
S6 A5	▪ Provide adaptation resources for NRM-dependent community groups and develop a adaptation program that acknowledges, measures and builds capacity for climate adaptation in the region	State and Local Government, Reef Catchments	Social Environmental	High	1-2 years

S7 Health & Wellbeing						
S7 A1	▪	Minimise breeding grounds for vectors of tropical diseases. Consider pest control options for host and/or vector species likely to increase with climate change including mosquitos. Improve vaccination programs for tropical diseases	State Government.	Social Economic Environmental	High	1-2 years
S8 Disaster Risk Management						
S8 A1	▪	Reduce risks of disasters (i.e.. through fire management planning/weed control to reduce fuel loads etc.)	State and Local Government, Reef Catchments	Social Economic Environmental	High	3-4 years
S8 A2	▪	Educate and improve community resilience to cope with natural disasters (improve awareness about existing risk)	Local Government	Social Economic	High	3-4 years
S8 A3	▪	Prepare natural areas to build resilience to cyclone impacts - prevent further loss of foreshore vegetation due to clearing, vehicle access and restore vegetation	State and Local Government, Reef Catchments	Social Economic Environmental	High	1-2 years
S8 A4	▪	Plan assessment program for natural areas post impact to assist recovery	Reef Catchments, State Government	Environmental	High	3-4 years
S8 A5	▪	Improve disaster recovery funding and resources for natural areas	Reef Catchments, State Government	Economic Social	High	1-2 years

SUMMARY

The details of how Australia will participate to deliver on the Paris Agreement to limit global warming are yet to be defined. Climate change is a global issue; however sustainability and addressing other regional change drivers need to be addressed at the regional level. Existing policy is complex, and to some extent not favourable to carbon farming in this region. However the region's stakeholders; given opportunities to work together across multiple (and not single issues) have demonstrated the ability that they can work together to deliver solutions that will address economic, social, cultural and environmental sustainability.

Reef Catchments will play an important role in continuing to bring stakeholders together with researchers to develop integrated, regionally-relevant solutions to the major issues facing our region.

CHAPTER 8

Implementation of the Climate Sustainability Plan

The next stage of this project will see the strategies and actions planned and implemented. Targets will be written to deliver the actions and time frames set around their delivery. Some of the actions can be implemented by integrating climate change mitigation and adaptation priorities with existing strategies, programs and initiatives. Importantly, effective adaptation in the region will require ongoing, regular and meaningful engagement of stakeholders from the community, environment sector, industries, planning and other organisations. However, implementation of many of the priority strategies and actions identified through this planning process will need supportive higher-level policy.

International, national and state inititives to address climate change

There are many grant programs or funding opportunties to assist in delivering actions set out in this plan.

As of April 2016, the Emissions Reduction Fund is the centrepiece of the Australian Government's policy suite to reduce emissions. The fund will provide incentives for emissions reduction activities across the Australian economy. The Carbon Farming Initiative Amendment Bill 2014 was passed by the Senate on 31 October 2014 and the House of Representatives on 24 November 2014. Rules and amendments to the legislation are administered by the Clean Energy Regulator. Australia's government policies that aim to cut greenhouse gas emissions (mitigation) include:

- The Emissions Reduction Fund (https://www.environment.gov.au/climate-change/emissions-reduction-fund) that is providing incentives for emission reduction activities across the Australian economy; and

- The National Energy Productivity Plan (NEPP) that was released in December 2015 (https://scer.govspace.gov.au/files/2015/12/National-Energy-Productivity-Plan-release-version-FINAL.pdf). This Plan brings together opportunities into a national plan to meet a National Energy Productivity Target to improve Australia's energy productivity by 40% by 2030

- The Renewable Energy Target that was amended mid-2015. The target aims for large-scale generation of 33,000 GWh in 2020, doubling the amount of large-scale renewable energy being delivered compared to current levels and that about 23.5% of Australia's electricity generation in 2020 will be from renewable sources (https://www.environment.gov.au/climate-change/renewable-energy-target-scheme)

- The Safeguard mechanism (https://www.environment.gov.au/climate-change/emissions-reduction-fund/publications/factsheet-erf-safeguard-mechanism) that will start on 1 July 2016 and will require Australia's largest emitters to keep emissions within baseline levels.

At a national level the primary mechanism for implementing priorities in this Plan are the land sector components of the Emissions Reduction Fund (transitioned from the Carbon Farming Initiative) (http://www.environment.gov.au/system/files/resources/1f98a924-5946-404c-9510-d440304280f1/files/emissions-reduction-fund-white-paper_0.pdf). To participate projects must meet commitments under an approved Emissions Reduction Fund method. New methods are constantly being developed and can be found at https://www.environment.gov.au/climate-change/emissions-reduction-fund/methods. As of February 2016, approved methods to reduce emissions in agriculture and vegetation management that may be pertinent to the MWI region are:

- Beef cattle herd management. Crediting is based on emissions reductions from pasture-fed beef achieved through efficiency gains, where emissions are reduced while beef production is maintained or increased.

- Estimating Sequestration of Carbon in Soil Using Default Values. This method sets out the detailed rules for implementing and monitoring offsets projects that sequester carbon in agricultural soils using certain types of management actions on project land and default values of sequestration.

- Sequestering Carbon in Soils in Grazing Systems. Applies to soil carbon sequestration projects in grazing systems and relies upon direct measurement of soil carbon to estimate sequestration

- Avoided clearing of native regrowth. Supports projects that protect native regrowth on agricultural land from further clearing. Projects using this method would need to demonstrate that regrowth has been cleared at least twice and can legally be cleared again.

- Avoided Deforestation 1.1. This method sets out the requirements for projects to reduce emissions by protecting native vegetation from being cleared.

- Designated Verified Carbon Standard projects. The draft method applies only to forest management projects previously approved under the Verified Carbon Standard, a voluntary international carbon offsets program.

- Human-Induced regeneration of a permanent even-aged native forest. This methodology involves the sequestration of carbon in permanent forests of native species. The forest is established through cessation of the activities causing suppression or destruction of vegetation regrowth.

- Measurement based methods for new forestry plantations. This methodology determination provides procedures for estimating abatement achieved through carbon sequestration from permanent plantings or for-harvest plantings on land previously managed for agricultural purposes and clear of forest.

- Native forest from managed regrowth. This methodology estimates greenhouse gas abatement achieved by human-induced native forest re-growth.

- Reforestation and Afforestation 2.0. This method streamlines the earlier method released for use under the Carbon Farming Initiative in mid-2012. The draft method sets out the detailed rules that landholders can use to cut their emissions by planting trees.

A number of other methods have been approved that include energy efficiency, facilities, mining, oil and gas, transport and waste and wastewater. These methods are applicable to local governments and industries.

The Emissions Reduction Fund (ERF) operates via a reverse auction process with the 2nd auction held in November 2015 with an average price of $12.25 tonne CO2 equivalents. As the process can be onerous to a famer/ land manager the best way to participate for smaller projects (revegetation/ avoided clearing, reduced agricultural emissions) projects is via an aggregator – an organisation that will work with individual land managers to 'aggregate' smaller projects and assist in participation in the reverse auction process.

The Queensland Government committed to developing a Climate Adaptation Strategy (Q-CAS) in 2015 to address current and future climate risks to the economy, environment, infrastructure and communities https://www.ehp.qld.gov.au/climatechange/adaptation.html. The government is investing $3 million over three years to support development and implementation of the Strategy. As part of the climate adaptation agenda, the Queensland Government will also provide hazard data at a scale appropriate for local level decision making and help increase knowledge about the effect of climate change on health, infrastructure and land use planning. $12 million will be invested through the Local Government Association of Queensland (LGAQ) to help coastal communities plan and prepare for storm tide, coastal erosion rising sea levels. It is vital that the Q-CAS process incorporates the work completed through the NRM Planning for Climate Change program with Queensland regional NRM Groups, including Reef Catchments.

Local government areas provide storm surge and erosion prone mapping on their websites. Mackay Regional Council has been preparing a Coastal and Inland Flood Hazard Adaptation Strategy (CIFHAS) since 2013; however has been hindered by changing policy at the state and federal level.

Environmental Offsets

Environmental offsets exist at a national level with the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999) and at the state level. Offsets usually apply when a development is assessed as having an impact on Matters of National Environmental significance.

Where appropriate, offsets are considered during the assessment phase of an environmental impact assessment under the EPBC Act 1999.

http://www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.

Under EPBC policy, carbon offsets, such as those available through the Australian Government's ERF are not eligible alongside environmental offsets. In many cases, the market price for carbon is likely to be significantly lower than those for environmental offsets (e.g. current maximum offset value in Mackay for marine plants/ mangroves is $30,000/ ha http://ecosure.com.au/news/advanced-offsets-for-landholders-and-graziers-in-queensland/). Recognition of both environmental and carbon sequestration outcomes would be more attractive for land managers to participate in carbon offsets and is also a matter of high priority for implementation of the Climate Sustainability Plan.

The Queensland Government introduced a new offsets framework on 1 July 2014. Environmental offsets may be required under number of existing Queensland for certain developments where there is an unavoidable impact on significant environmental values. The framework is based on 'avoid, mitigate, offset' for development proposals http://www.ehp.qld.gov.au/assets/documents/pollution/management/offsets/offsets-policyv1-1.pdf

Once an administering agency has decided that a prescribed environmental activity is required to provide an offset, the offset will be delivered in accordance with the Queensland environmental offsets framework established under the Environmental Offsets Act 2014, Environmental Offsets Regulation 2014 and the Queensland Government Environmental Offsets Policy (policy). An offset should compensate for the full suite of natural and cultural values impacted by the prescribed activity, including current and future values relating to the provision of ecological services (such as clean air, water and carbon storage), recreation and tourism opportunities, grazing, scenic amenity, and cultural and spiritual significance. It is unclear from what is outlined in these polices whether carbon offsets can also be applied to land under environmental offsets.

Voluntary Carbon Markets

Voluntary markets are expected to be the way for carbon offset markets to progress in Australia since repeal of the carbon pricing mechanism. However, there are currently no linkages between international carbon markets and Australian brokers/aggregators seeking opportunities to link with the Verified Carbon Standard (VCS) – an international carbon market discussed further below.

Within Australia there used to be many programs supporting the delivery of voluntary markets, but these have largely been discontinued. The Australian Government's Greenhouse Friendly™ program operated from 2001 to June 2010 and was part of the Australian Governments Greenhouse Challenge program. Through this program Australian businesses were able to market carbon neutral products and services, deliver greenhouse gas abatement and give Australian consumers greater purchasing choice. All Greenhouse Friendly™ product and service providers' offsets were sourced from Greenhouse Friendly™ approved abatement activities only. These abatement activities offered permanent, independently verified carbon offsets which represented emissions reductions or sequestration which had contributed to a net reduction of Australia's greenhouse gas emissions. The program provided an effective and successful avenue for participation in the voluntary carbon market in Australia (https://www.environment.gov.au/climate-change/carbon-neutral/greenhouse-friendly). This program was replaced by the National Carbon Offset Standard (NCOS). NCOS provides a benchmark for businesses and other organisations voluntarily seeking to be carbon neutral for their operations, products, services or events https://www.environment.gov.au/climate-change/carbon-neutral/ncos.

The Carbon Market Institute (CMI) is working to keep the Australian Voluntary market alive (http://carbonmarketinstitute.org/home/market-development/voluntary-markets/). CMI aims to grow the Australian voluntary market by facilitating knowledge exchange and commercial interaction between the key buy/sell side market participants. The voluntary market has an opportunity to leverage expertise developed by compliance market participants and translate this into increased deal flow.

The Verified Carbon Standard (VCS) is a voluntary greenhouse gas reduction program that works hand-in-hand with public and private sector leaders all across the globe to lead a greenhouse gas reduction program that delivers massive emission reductions across the world (http://www.v-c-s.org/). Linkages within Australia appear limited, however, carbon offsets generated by the Tasmanian Land Conservancy are covered by the VCS. The VCS also has a greater range of methods for carbon offsets than those of the ERF including reduction of nitrous oxide in agricultural crops that would have applicability for the local sugar industry.

International Carbon Markets

Prior to amendments to national carbon policy, there was intention to link Australian carbon markets with European carbon markets. At this stage there is no information whether the Australian Government is still considering linking with the European market; however is unlikely with the current structure of Australian policy.

The European market is an Emissions Trading Scheme (ETS) that operates on a 'cap and trade' principle where limits (the cap) is set on the total amount of greenhouse gases that can be emitted. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005. By 2030, the Commission proposes, they would be 43% lower (http://ec.europa.eu/clima/policies/ets/index_en.htm). The EU – ETS has been severely over-allocated leading to a price collapse in carbon, with most recent trading the latest carbon price in February 2016 at 5.57 Euro or $AUS8.75 (http://carbon-pulse.com/15220/).

Future Directions for Climate Change Adaptation and Mitigation

A clearer articulation of policy and markets in Australia will encourage participation by farmers and land managers in emission reduction activities and adaptation measures, especially if accompanied by greater compensation for activities that address biodiversity, landscape resilience and carbon sequestration. Policy relating to climate change has been a moving goal post during engagement and development of the Climate Sustainability Plan. Greater support for mitigation and adaptation to climate change is urgently required in policy at all levels of government and to assist, where possible, further decline in the regions biodiversity and impact on the sustainability of the MWI NRM region.

Engagement with different land use sectors needs to be 'framed' to suit the audience. Scepticism can be high with regard to climate change and the role of humans; in some sectors. There is scope for the agricultural sector to make more use of seasonal forecasting tools (e.g CliMate apps http://www.australianclimate.net.au/) in making land management decisions. The regions' Local Governments are engaged and aware of the issues. Projections for increases in return periods for extreme events (e.g., high temperatures, heavy rainfall events) will incur substantial economic and social cost and will affect building codes and plans for the development of major infrastructure (e.g. highways, buildings, bridges, urban settlements) the

Further, development and approval of more methods need to be approved under the ERF to provide incentives to the region's industries to reduce emissions or maintain carbon storage in the local landscape. In particular; methods to reduce nitrous oxide emissions in sugarcane would be of great value as well as recognition of the value of carbon storage in coastal and marine ecosystems.

Reef Catchments plans to implement a monitoring and review framework to assess achievements in implementing this plan. Regular review of actions will be conducted to keep current with best practices and align with latest science.

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GLOSSARY

Carbon Sequestration	The process involved in carbon capture and the long-term storage of atmospheric carbon dioxide (CO_2).Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change.
Climate Adaptation Responses	It involves taking practical actions to manage risks from climate impacts, protect communities and strengthen the resilience of the economy. Adaptation refers to dealing with the impacts of climate change. Mitigation means dealing with the causes of climate change by reducing emissions
Climate Change	A change in the state of the climate that can be identified by changes in the mean and/ or variability of its properties, and that persists for an extended period, typically decades or longer
Climate Variability	Refers to the variability in general climate patterns that occur over time. The average climate of summer is warmer than winter but seasons vary from year to year with some summers hotter or wetter than others in different years and winters that may be cooler or drier in a certain year. Climate drivers that influence climate variability are a result of interactions between the ocean and the atmosphere, e.g. the El Niño Southern Oscillation (ENSO) plays a large role in climate variability from year to year.
Denitrification	A microbial facilitated process of nitrate reduction (performed by a large group of heterotrophic facultative anaerobic bacteria) that may ultimately produce molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxide products.
El Nino	Phase occurs when the trade winds along the equator lessen and sea surface temperatures are higher than normal in the eastern Pacific (and cooler over northern Australia), which brings reduced rainfall to eastern Australia.
Emissions	Emission of air pollutants, notably: Flue gas, gas exiting to the atmosphere via a Flue. Exhaust gas, flue gas generated by fuel combustion. Emission of greenhouse gases, which absorb and emit radiation in the thermal infrared range.
Emissions Reduction Fund	The centrepiece of the Australian Government's policy suite to reduce emissions. The fund will provide incentives for emissions reduction activities across the Australian economy.
Indian Ocean Dipole (IOD)	A feature of the equatorial Indian Ocean characterised by changes in sea surface temperatures that affect year to year climate variability across Australia and is broadly correlated with rainfall across central and southern Australia
Kyoto protocol	The agreement commits nations to keep the global warming level to below 2°C with an aim of 1.5°C and calls for global emissions to peak as soon as possible. In mid-December 2015, 196 nations, including Australia, signed the Paris agreement
La Nina	La Niña phase occurs when trade winds strengthen; sea surface temperatures are lower than average in the eastern Pacific and higher over northern Australia. La Niña is associated with higher than average rainfall over eastern Australia, with increased risk of tropical cyclones.

Ocean acidification	The ongoing decrease in the pH of the Earth's oceans caused by the uptake of carbon dioxide (CO2) from the atmosphere
Representative Concentration Pathways	Four emissions scenarios entitled Representative Concentration Pathways (RCPs) that describe plausible trajectories of future greenhouse gas and aerosol concentrations to 2100 (Turton 2014), which are RCP2.6, RCP4.5, RCP6 and RCP8.5.
Seawater intrusion	The movement of saline water into freshwater aquifers, which can lead to contamination of drinking water sources and other consequences.
Storm Surge	A storm surge is a rise above the normal water level along a shore resulting from strong onshore winds and / or reduced atmospheric pressure. Storm surges accompany a tropical cyclone as it comes ashore. They may also be formed by intense low-pressure systems in non-tropical areas.
Traditional Owners	A traditional owner group is also defined in that section to mean a group of Aboriginal persons who authorise certain Indigenous Land Use Agreements under the Native Title Act, or native title holders.
Weather	Experienced on a day-to-day basis as a result of the constant changing state of the atmosphere. Weather is characterised by the temperature, wind, rain, clouds and other weather elements (IPCC 2007a) such as cyclones. Different to climate which typically defines the average weather over a period of time, typically a minimum of 20 years

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APPENDIX 1

Outputs Climate Futures Tool analyses from SILO Data Drill and historical seasonal data

Climate Futures Tool

RCP's (representative concentration pathways) have been developed by the climate modelling community to explore credible climate futures. There are four emissions pathways RCP2.6, 4.5, 6 and 8.5. RCP 4.5 and RCP 8.5 are the climate futures that have been explored in the Climate Sustainability Plan. A brief explanation of their meanings are:

- RCP 4.5 global emissions peak around 2040 and atmospheric CO2 concentrations reach 540 ppm by 2100
- RCP 8.5 represents a future with little curbing of global emissions with atmospheric CO2 concentrations continuing to rise reaching 940 ppm by 2100.

The Climate Futures Tool generates climate future scenarios that provides the likely climate future for different cases best, worse and maximum consensus (where most models agree). The consensus refers to agreement amongst the models. Using the tool further provides a 'best fit' to the climate future and a representative model that can be used to superimpose baseline climatology (for any meteorological office) to determine likely change.

Table A1.1 *below provides the results generated from the Climate Futures Tool – note that only the maximum case is presented in Chapter 3.*

Climate Future	Case	Climate Future	Consensus	Representative Model
2030 RCP 4.5	'Best'	Slightly warmer (<0.5 C) & little change in rainfall (-5 to+5%)	Very low	
	'Worst'	Warmer (0.5-1.5 o C) & drier (-5-+5%)	Low	
	'Maximum consensus'	Warmer (0.5 to 1.5 o C) & little in rainfall change (-5 to +5%)	Moderate	GISS-E2-R-CC
2030 RCP 8.5	'Best'	Slightly warmer (<0.5 C) & little change in rainfall (-5 to+5%)	Very low	
	'Worst'	Warmer (0.5-1.5 o C) & drier (-5-+5%)	Moderate	
	'Maximum consensus'	Warmer (0.5 to 1.5 o C) & little change to drier (-15 to +5%)	High	GISS-E2-R-CC

Climate Future	Case	Climate Future	Consensus	Representative Model
	'Best'	Warmer (0.5 to 1.5 o C) & little in rainfall change (-5 to +5%)	Moderate	
	'Worst'	Hotter (1.5 to 3 C) & much drier (<-15%)	Very Low	
	'Maximum consensus'	Warmer (0.5 to 1.5 o C) & little in rainfall change (-5 to +5%)	Moderate	CCSM4
2050 RCP 8.5	'Best'	Warmer (0.5 to 1.5 o C) & little change (-5 to +5%)	Low	
	'Worst'	Hotter (1.5 to 3 C) & much drier (<-15%)	Very Low	
	'Maximum consensus'	Warmer (0.5 to 1.5 o C) & little change to wetter (-5-+15%)	Moderate	Bcc-csm1-1
2070 RCP 4.5	'Best'	Warmer (0.5 to 1.5 o C) & little in rainfall change (-5 to +5%)	Moderate	
	'Worst'	Hotter (1.5 to 3 o C) & much drier (<-15%)	Very Low	
	'Maximum consensus'	Warmer (0.5 to 1.5 o C) & little in rainfall change (-5 to +5%)	Moderate	GISS-E2-H-CC
2070 RCP 8.5	'Best'	Hotter (1.5 to 3 o C) & little rainfall change (-5 to +5%)	Low	
	'Worst'	Hotter (1.5 to 3 o C) & much drier (<-15%)	Very Low	
	'Maximum consensus'	Hotter (1.5 to 3 o C) & little to wetter rainfall change (-5 to 15%)	Moderate	CCSM4

Additional analyses for baseline climatology was also produced – based on four seasons for all areas examined. This is presented in Table A1.2

Table A1.2 *20-year climatology (1986-2005) for four seasons for Mackay, Eungella and Proserpine*

	Dec-Feb			Mar-May			Jun-Aug			Sept-Nov		
Site	Temp (oC)		Rainfall (mm)	Temp (oC)		Rainfall (mm)	Temp (oC)		Rainfall (mm)	Temp (oC)		Rainfall (mm)
	Max	Min		Max	Min		Max	Min		Max	Min	
Eungella	30.5	20.6	659.0	26.4	16.9	411.7	21.7	10.6	200.3	28.2	16.4	185.5
Proserpine	31.7	22.9	806.1	28.5	19.0	410.2	24.8	12.3	87.1	30.1	17.6	150.3
Mackay	30.3	23.4	708.3	26.6	20.1	482.8	22.1	14.1	150.8	27.7	19.6	150.2

Table A1.3 *Projected change in climate – four seasons (for the maximum consensus case) for a range of climate variables for NRM regions in the Wet Tropics cluster (expressed as °C change for temperature and percentages for rainfall, humidity and evapotranspiration). Note: Humidity and evapotranspiration derived from SILO data drill*

	2030		**2050**		**2070**		**2090**	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Model Consensus	Moderate	High	Moderate	Moderate	Moderate	Moderate	Low	Low
Climate Variable								
Temperature oC								
Max (Dec-Feb)	0.6	0.6	1.1	1.2	1.1	2.3	1.1	2.2
Min (Dec-Feb)	0.7	0.6	0.9	1.2	0.7	2.1	1.2	2.1
Rainfall (Dec-Feb) %	7	0	4	6	0	5	3	-12
Temperature oC								
Max (Mar-May)	0.6	0.7	1	1.3	0.9	2.2	1.5	2.4
Min (Mar-May)	0.5	0.4	1.1	1.3	0.8	2.1	1.3	2.3
Rainfall (Mar-May) %	-2	-10	6	-2	5	20	-9	1
Temperature oC								
Max (Jun-Aug)	0.7	0.7	1.1	1.2	1	2.1	1.4	2.4
Min (Jun-Aug)	0.7	0.6	1	1.2	0.7	2.3	1.3	2.3
Rainfall (Jun-Aug) %	9	-4	2	-10	2	17	5	3
Temperature oC								
Max (Sep-Nov)	0.7	0.7	0.9	1.2	0.8	2.1	1.2	2.2
Min (Sep-Nov)	0.8	0.6	1	1.3	0.5	2.2	1.3	2.1
Rainfall (Sep-Nov) %	2	-5	5	7	-11	13	22	-3
Humidity %								
Dec-Feb	0	1	0	1	0	0	0	0
Mar-May	1	0	-1	-1	3	0	-1	1
Jun-Aug	2	0	0	1	1	1	-1	4
Sep-Nov	0	1	0	1	1	1	0	1
Solar radiation %								
Dec-Feb	0	0	-1	1	1	-4	-2	-1
Mar-May	0	1	-1	0	-1	-3	2	-2
Jun-Aug	0	0	0	0	0	-1	0	-1
Sep-Nov	0	0	-1	1	0	-2	-1	-1
Evapotranspiration %								
Dec-Feb	2	3	2	5	3	6	1	7
Mar-May	3	3	3	5	4	2	6	9
Jun-Aug	3	3	5	6	3	8	5	11
Sep-Nov	3	3	2	4	3	7	3	7

APPENDIX 2

Supporting documents to Reef Catchments' Climate Sustainability Plan

Participatory Processes used to support development of the Climate Sustainability Plan

1. Background: A logical, comprehensive and transparent planning process, incorporating best available information and collaboration with government, community and other stakeholders

Framing the planning and research process

As described in Chapter 1 of the Plan, it was recognised at the outset that there a degree of mistrust and confusion in the community in relation to climate change. Thus, communications were framed in terms of developing a Plan to foster ecological, social, cultural and economic sustainability. Discussions were held within the context of a changing climate, rather than being focussed primarily on climate change. Furthermore, while there is an emphasis in this Plan on maintaining biodiversity, the planning process integrated this with consideration of opportunities to improve socio-economic resilience through change in natural resource management. So, while climate change and biodiversity are of central significance, the process was framed around the issues that stakeholders identify as those that most strongly affect communities - the key 'drivers of change' - in the region. Climate change is obviously one key driver of change, but the planning process created scope to consider climate change in an integrated way with other important drivers of more immediate priority to regional stakeholders.

During early 2013, two workshops were held to develop preliminary understanding among the members of the WTC Brokering Hub (see Chapter 1 of the Plan) about the various issues faced by the four NRM regions in the WTC NRM cluster in relation to planning for climate change (Bohnet et al., 2013). Reef Catchment's Climate Project officer participated in these workshops, together with staff from Terrain, Cape York NRMs and Torres Strait Regional Authority. The workshops helped to highlight specific scientific information needs required to develop potential climate adaptation responses and set the context for subsequent work on synthesising relevant research in the WTC NRM cluster.

At this level, three key drivers of change were identified for the MWI region (Bohnet et al., 2013):

- Conditions in the mining, sugar and cattle grazing industries;
- Local and State government policies;
- Population growth and associated impacts on urban and peri-urban areas, including availability of agricultural land.

This information was subsequently used to focus stakeholder engagement in terms of seeking industry representation and engaging with Local and State government staff. Within the context of these higher-level drivers of drivers of change, specific focal issues in the context of climate change were identified for the MWI region (Bohnet et al., 2013):

- Coastal development and increased risk of storm surge;
- Expanding port development;
- Projects of State significance;
- Scepticism around climate change information; and
- High natural variability in rainfall.

Identification of these focal issues helped to inform discussions with researchers about knowledge gaps, and how work in the research consortium could build the capacity of NRMs to plan for climate change adaptation. Knowledge gaps were compiled for the Wet Tropics NRM cluster region (see Appendix to this document), and formed the framework for two subsequent synthesis reports on climate change impacts (link to Hilbert et al., 2013) and potential adaptation opportunities (Moran et al., 2014). Drivers of change were independently identified during a series of workshops with key stakeholders in the MWI region (Chapter 2 of the Plan). Much of the discussion that has informed the development of this Plan revolved around risk management under likely future conditions.

Incorporating best available information into the Plan

Reef Catchments has engaged with a wide range of groups and processes to ensure that best available information is incorporated into the Plan, both directly and indirectly by informing the development of priority strategies by stakeholders.

Through participation in the Brokering Hub, Reef Catchments influenced the direction of research conducted within the scientific team, and contributed to the co-development of stakeholder information tools arising from this work. The Wet Tropics Brokering Hub (See Chapter 1) was established to improve the relevance, application and transfer of scientific knowledge generated in the project, intended to facilitate the incorporation of best available science into NRM planning processes. From 2013, Reef Catchments participated in ten Brokering Hub meetings and associated workshops and reviewed and contributed to the preparation of technical reports (Hilbert et al., 2013, Moran et al. 2014). Reef Catchments' Climate Officer also worked on the co-development of summary or stakeholder engagement products associated with the technical reports, including:

- a short film interpretation (Wet Tropics NRM cluster, 2014) of the key messages from the climate change impacts and issues report (Hilbert et al., 2014b);
- a series of summary fact sheet for six key NRM sectors (Wet Tropics NRM cluster, 2015a); and
- an additional information resource showing how knowledge of climate change has accumulated over time (Wet Tropics NRM cluster, 2015b).

These outputs were further adapted for presentations and display material during stakeholder workshops by Reef Catchments' Climate Project Officer. In this way, information from these outputs improved stakeholder awareness of the issues and informed the development of practical and regionally-relevant strategies.

In addition to participation in the Brokering Hub, Reef Catchments also worked with the research consortium to plan and deliver specific stakeholder workshops and events. Researchers from this team participated in all multi-stakeholder workshops, directly delivering scientific knowledge into the participatory planning process.

A parallel engagement process with Yuibera and Koinmeburra Traditional Owners was implemented by the research team in collaboration with Reef Catchments. This enabled expertise about cultural heritage mapping to be incorporated into Reef Catchments' planning process and complemented Reef Catchments' work to re-establish relationships with Traditional owner groups in the region. This work has identified potential climate change impacts on specific cultural values and provided information directly back to the TO groups in developing strategies and actions to maintain cultural connections and access to traditional country and resources.

In addition to cluster-based research projects, the Commonwealth's *NRM Planning for Climate Change* program funded two national-scale projects intended to support NRM planning processes. The Climate Change in Australia (CCIA) project delivered downscaled climate projections for the Wet Tropics Cluster, as well as a Climate Futures Tool which enables impact assessment at local scales. Reef Catchments has made extensive use of these outputs to develop understanding of the risks to the MWI region (see Chapter 4), and to inform discussions with stakeholders. The Reef Catchments Climate Project Officer also participated in a one-day workshop delivered by the CCIA project, and completed a four-day technical training in the application of the Climate Futures Tool.

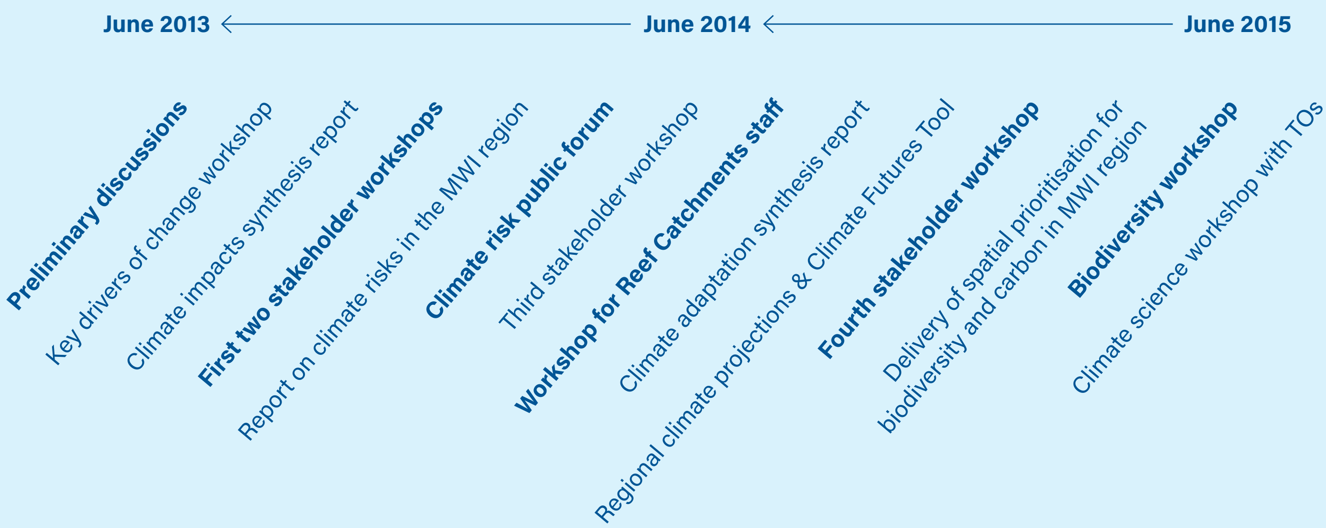
The second national-scale project supported by the Commonwealth program is AdaptNRM. This project has so far delivered modules on adaptive planning in NRM (http://adaptnrm.csiro.au/adaptation-planning/), climate change and invasive plant species (http://adaptnrm.csiro.au/invasive-plants-climate-change/), climate change impacts on biodiversity(http://adaptnrm.csiro.au/biodiversity-impacts/) and options for biodiversity adaptation to climate change (http://adaptnrm.csiro.au/biodiversity-options/). Reef Catchments has contributed to review of AdaptNRM outputs and relevant information has been incorporated as appropriate.

In addition to using information generated through the Brokering Hub, CCIA and AdaptNRM, Reef Catchments contracted RPS Australia East Pty Ltd to develop a series of climate impact maps to support discussions with stakeholders (See Chapter 4). Reef Catchments also invited spokespeople from emergency services and the insurance industry to speak during stakeholder engagement workshops. Finally, Reef Catchments organised a public forum on climate risk in the MWI landscape at which researchers from a range of institutions presented on climate change impacts, especially in coastal areas.

Stakeholder engagement, consultation and participation in MWI Climate Sustainability planning processes

Strategies and actions for adapting to climate change in the MWI region (Chapter 7) were developed through an iterative process of collaboration with government, community and other key stakeholders and the WTC research consortium. Key events in the timeline of stakeholder engagement are depicted in Figure 1, below.

Figure A2.1. *Indicative timing of major stakeholder engagement activities, together with the delivery of key supporting resources and tools. Note that informal engagement with stakeholders had continued throughout the life of the project and is ongoing.*



Initial contact and engagement

Targeted stakeholder engagement in the planning process sought representation of the diversity of sectors and organisations involved in natural resource management and emergency management in the MWI region. Stakeholder engagement occurred via one-on-one meetings and in multi-sectoral workshops. The overall approach aimed to break down barriers, provide networking opportunities and establish a platform for developing integrated, collaborative strategies and a shared vision for the future of the MWI region. The emphasis of workshops was on the presentation and discussion of locally-relevant information. Engagement with certain stakeholders was not successful in particular state government, Regional Development Australia and industries associated with the resources sector.

During early 2013, preliminary, informal discussions with stakeholder groups about climate change impacts and adaptation opportunities in the MWI region were initiated by the Climate Project Officer through phone calls and face-to-face meetings. These discussions established greater awareness of Reef Catchments' climate change planning process and opportunities for involvement, provided preliminary information about climate change projections, and identified key areas of concern for different stakeholder groups. Many additional opportunities have been taken to work with key stakeholders during the development of the Plan. For example, one-on-one meetings were held with a range of stakeholders to discuss opportunities to integrate work related to this plan.

Involving Traditional Owners

Special effort was made to engage with Traditional Owner (T.O.) groups in the MWI region. Reef Catchments had a stated aim of re-establishing relationships more generally with T.O. groups in the region and T.O. groups had also been identified as a key stakeholder group for the climate planning process. Furthermore, the WTC research consortium contained special expertise in cultural heritage mapping with traditional owner groups. Working through the Traditional Owner Reference group (T.O.R.G.) and engagement protocols established through Reef Catchments, Yuibera and Koinmerburra T.O.s collaborated in a project to map cultural heritage and develop understanding of impacts of climate change on cultural heritage. This process also developed the capacity of T.O. groups within the MWI region to participate in multi-stakeholder workshops.

Stakeholder workshops and public forum

Following from initial stakeholder contact, a series of five stakeholder workshops was held, including one workshop in each of two major centres (Mackay and Proserpine) during February 2014, and three full-region workshops in June 2014, June 2015 and September 2015. The three workshops in 2014 were framed in terms of 'Envisioning possible futures for the MWI NRM region' within the overarching context of environmental, social, cultural and economic sustainability. The first workshops identified participants' values and the key drivers of change in relation to these. The June 2014 workshop reviewed the key drivers of change identified in the first workshops and began a process of developing strategies to address these. Break-out groups were formed around each of the four key drivers of change (see 4.2(i), below) to identify and rank strategies. This workshop also hosted a presentation from

Steel Pacific Insurance Brokers, entitled Our changing planet, your insurance. The workshop in June 2015 continued work on prioritising strategies and identifying potential actions for addressing risks and making the most of opportunities.

Stakeholder representation at the June 2015 workshop was similar to that for the 2014 workshops. Workshop activities facilitated work within sectoral groups, with opportunity for cross-sectoral presentation and discussion. The fifth multi-stakeholder workshop focused on developing narrative strategies and spatial maps aimed at maintaining landscape resilience, connectivity and carbon storage in the MWI region. Aside from a single cane grower, stakeholder representation at this workshop was dominated by organisations involved in conservation and natural resource management, i.e., Local Government, Queensland Department of Environment and Heritage Protection, Queensland Parks and Wildlife Services officers, Mackay Conservation Group, T.O.'s, Landcare, and several Reef Catchments staff. During break-out activities, participants worked within one of the three Landcare regions (Sarina, Whitsunday or Mackay). Activities focused around base maps of the Landcare regions, with overlays for risks such as storm tide inundation with projected 0.8m sea level rise.

The workshop in June 2015 aimed to raise awareness among stakeholders of the updated regional climate change projections delivered through the Climate Change in Australia project which had recently been released and downscaled climate impact assessments conducted using the Climate Futures Tool. The workshop used these as the basis for initiating discussion of key climate change adaptation and mitigation for each sectoral group. This process was framed in terms of a risk matrix approach, and was supported by discussions held with stakeholders prior to the workshop about the climate variables of most interest to their sector. The workshop also aimed to highlight the strategies and actions developed during previous workshops and to establish associated working groups.

In May 2014, a community forum on *Climate risk* in the coastal zone was also organised to support the stakeholder information process and involved expert speakers on the value of coastal and marine ecosystems in a changing climate, update on Mackay Regional Council's Coastal and Inland Flood Hazard Adaptation Strategy (CIFHAS) and current and future climate risks in the region.

Reef Catchments staff workshop

A workshop for internal Reef Catchments staff was also held in June 2014. This workshop was aimed at facilitating the integration of climate change impact and adaptation information into Reef Catchments' plans and processes. It is perceived that climate change has largely been framed as a separate issue within the organisation, exemplified by the separation of this Climate Sustainability Plan from the MWI NRM Regional Plan. This workshop focused on developing understanding of the potential impacts of climate change in the region, and exploring how to incorporate this information into Reef Catchments planning and operational activities. A set of priority actions for Reef Catchments was developed (see Chapter 7). During the workshop, the issue of Reef Catchments' role in the context of climate change adaptation was raised. It was agreed that Reef Catchments' role is to work with community stakeholders to facilitate adaptation of land management by humans. Although Reef Catchments also has a role in facilitating the adaptation of natural systems, this is fairly undefined and will depend on continuing work with other, lead organisations. Key issues included increasing understanding of the role of Reef Catchments in interventions such as the translocation of animals and plant species.

It was also recognised that Reef Catchments currently works to build resilience in *response* to *current* impacts but workshop participants identified the need to more explicitly *anticipate future* impacts. Since transformative change is likely to derive from extreme events (e.g., extensive inundation of residential areas from storm surge), it is a priority for Reef Catchments to develop the capacity to anticipate thresholds and tipping points, particularly in relation to temperature, sea level rise and events such as bush fires, flooding and tropical cyclones.

Appendix: NRM priority science information needs, October 2013

Background

The key science information needs expressed by NRM groups in the Wet Tropics Cluster (WTC) have been grouped into three sectoral themes (Physical, Biodiversity and Socio-Cultural-Economic). Each of the science needs statements has subsequently been categorised as a Topic or a specific issue within a topic through work in the Science synthesis node.

The science information needs have largely been articulated in a document prepared in response to the development of an application by the research consortium for Stream 2 funding, in which the Wet Tropics cluster NRM groups identified key areas of interest and priority deliverables from the Stream 2 project. In May 2013, the Participatory Scenarios research node of the Stream 2 project held a workshop with the WTC NRM groups to identify key issues and drivers of change; the outcomes of this workshop were used to identify other key information needs. The subsequent list was circulated for addition or amendment by the WTC NRM partners in September 2013.

A2.1. *Physical science – climate change projections for the wet tropics cluster*

Topics	Specific issues
Scenarios for temperature and rainfall	▪ inc. extreme high and low
Scenarios for oceans	▪ sea level changes ▪ sea surface temp ▪ acidification
Implications for hydrological cycles and water quality	▪ evaporation ▪ point source and diffuse water pollutants
Change in frequency of extreme weather events	▪ cyclones ▪ drought ▪ flood ▪ storm surge ▪ marine intrusion ▪ erosion
Change in fire regimes	

Biodiversity

Topics	Specific issues
Change in distribution and abundance of invasive species	▪ impacts ▪ emergent risks ▪ priorities ▪ potential adaptation responses
Change in extent and distribution of terrestrial and marine vegetation communities	▪ consider water stress ▪ wetlands, segrass, mangroves ▪ island landscapes ▪ limitations on ability to shift (e.g., altitude, coastal development) ▪ fire
Change in abundance and distribution of key terrestrial, coastal and marine species	▪ esp. Turtles (distribution, heat stress, sex ratio) ▪ fish (for harvest but also higher order effects) ▪ dugong ▪ corals (esp. bleaching) ▪ cassowary ▪ endemic species ▪ species of cultural significance ▪ range shifts ▪ connectivity (incl. condition) esp. migratory species ▪ critical thresholds ▪ impacts of extreme events ▪ vulnerable and resilient taxa
Implication for disease	▪ Human and wildlife ▪ vectors (mosquitoes, birds, pigs)

Socio-cultural-economic

Topics	Specific issues
Indigenous knowledge of past climate adaptation	▪ previous land management practices ▪ refugia ▪ changes in systems
Impacts on Indigenous culture and livelihoods and adaptation opportunities	▪ liveability ▪ changing resources/access (water, vegetation, key species); cultural practices ▪ tourism (fire, cyclones, storm surge, infrastructure) ▪ adaptation (e.g., carbon abatement/sequestration)
Impact on human infrastructure, mainland and islands	▪ sea levels ▪ flow events ▪ fire ▪ cyclones ▪ new locations and requirements
Impacts on rural and primary industries	▪ agriculture (type, scale, productivity; inc sugar cane, mining) ▪ adaptation opportunities ▪ realistic opportunities for carbon bio-sequestration and abatement
Ecosystem services	▪ Carbon abatement (e.g., fire management) ▪ carbon sequestration (marine and terrestrial) ▪ revegetation
Tourism	▪ Impacts of loss of environmental values (habitats/species) ▪ climate changes (e.g., too hot/ more frequent cyclones)
Cost benefit analysis of adaptation vs BAU	
Changes in land use patterns	▪ economic implications ▪ social implications
Assessment of community (sectors) adaptation capacities	▪ capabilities ▪ interests ▪ aspirations
Changes in practices to build social and ecological resilience	

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