New and Emerging Issues Affecting Climate Change Adaptation on the Environment, Economic Development and Settlement Patterns of the Mitchell River Catchment.

Thesis submitted by
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Statement on Ethics

The research received ethical clearance from the James Cook University's Ethics Review Committee (Approval Number H4033). A copy of this approval is included as Appendix A. The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the National Statement on Ethics Conduct in Research Involving Humans, the Joint NHMRC/AVCC Statement and Guidelines on Research Practice, the James Cook University Policy on Experimentation Ethics. Standard Practices and Guide Lines and the James Cook University Statement and Guidelines on Research Practice.

Abstract

Climate change is predicted to directly affect the physical environment of Tropical northern Australia. Physical impacts across the tropical region are modelled to present as more severe weather and physical events, with increasing variability within the cycle. Ecosystems are expected to adapt to events with variability in plant and animal introduction, distribution and fecundity. Soil characteristics will need to adapt to changes such as in salinity, structure, transpiration and fertility. The flora and fauna of the region will be threatened by climate change effects, while pest weeds and feral animals may exploit favourable niches in the affected environment. Impacts on the human population and economy will require sustainable adaptation, planning and implementation strategies. To understand the integrated nature of climate change impacts within the context of a whole community, a tropical remote river basin was selected as the focus of study.

The aims of this study were to:

1. Investigate actual and predicted effects on the environment, human population and economy of the Mitchell River catchment and determine whether they will sustainably adopt community-based climate change adaptation strategies or rely on externally imposed regulations.
2. Develop sustainable mitigation plans and strategies for the community, which are directed toward managing the existing and projected planning for climate change adaptation within the catchment.

The methodology employed the adoption of both physical (quantitative) and social scientific (qualitative) concepts to collect, analyse and synthesise results that indicate

this environment and its marginal economy is vulnerable to the effects of climate change. The population is at risk from the effects on physical and psychological health and safety issues. The economy of the catchment will be impacted through a predicted decline of productivity in the pastoral and agricultural industry, with an increase in input costs. However, the existing and proposed mitigation and adaptation strategies should assist the environment, community and economy to reduce its vulnerability to the effects of the emerging disaster and enable growth of resilience. The key to implementing these climate disasters mitigating strategies is centred on community development and preparedness, which is formed by the recognition and development of the existing human skill set. Education and training will develop the potential of community members to respond to disaster.

These findings and recommendations are submitted as one strategy in a whole-of-nation resilience-based approach to climate disaster management. This recognises that a national, coordinated and cooperative effort is needed to enhance the community's capacity to withstand and recover from climate-induced disasters. Connected, organised, and resilient communities are proven to be better able to adapt to a disaster and sustainable resilience is formed with those events that transpire during initial planning and operation stages of a disaster response.

A potential outcome from this study is that this Community Preparedness Model may inspire other communities to modify, adapt and adopt relevant concepts and/or strategies to improve their adaptive capacity, thereby raising their community and environmental prospects for survival and recovery in the event of enhanced disasters that may accompany climate change.

Table of Contents

Contents

List of Figures

List of Tables

List of Plates

Chapter 1

Introduction

1.1 Introduction

Anthropogenic processes and emissions have created an increase in atmospheric and oceanic thermodynamic energy levels. This has driven change in the global climate, creating environmental change in the biosphere International Panel on Climate Change, IPCC, (2013, p. 11), Bureau of Metrology (BOM State of the Climate, 2014). The long-term effects of the change in climate on the environment, human population and economy of Australia are predicted to be significant, long term, and severe (Department of Climate Change, 2010, p. 4). The impacts of climate change are complex and highly variable from one location to another, although communities and the environment will face common processes of adaptation and increased hazard impact. This study focuses on the complexity of climate change and its inter-related impacts through analysis of all factors in one river catchment, the Mitchell River in North Queensland (72 000km^2). Here, due to a predicted temperature-induced increase in the elevation of cloud layer, a reduction in the quantity of water harvested from the clouds by the rain forest is expected, which results in a reduction of the Mitchell River headwater flow from the cloud forests of Mount Lewis (Pye & Gadek, 2004, p. 620) located 20 km west of Port Douglas. To the north west on the estuarine coast (425km away), Castillo (2009) found the coast to be affected by rising sea level. The vegetation of the catchment indicates subtle changes, where a range of invasive plant species which has filled a niche, initiating a hazard in the fire regime Mitchell River Watershed Management Group- (MRWMG-pests, 2014). The floristic diversity of the savanna is also being affected, reducing grazing land productivity while increasing protection for pest weeds and animals. Human activities have, and are, impacting the

environment via erosion and sedimentation caused by vehicle movement, grazing pressure and abandoned mining pollution of the waterways. Human-made changes in the fire regime have altered the floristic diversity and ground cover North Australian Fire Information, (NAFI, 2015; MRWMG, 2014).

The Mitchell River catchment (Figure 1) located across the base of Cape York Peninsula, displays a range of human, economic and environmental characteristics distributed across its five biogeographical regions (MRWMG, 2014). Future climate change events are expected to affect most of these characteristics. The response by community and government can help to ameliorate some of these problems and assist the population and economy to adapt and strive towards resilience:

> *Risk from a changing climate comes from vulnerability (lack of preparedness) and exposure (people or assets in harm's way) overlapping with hazards (triggering climate events or trends). Each of these three components can be a target for smart actions to decrease risk* (International Panel on Climate Change [IPCC], 2014, p. 1).

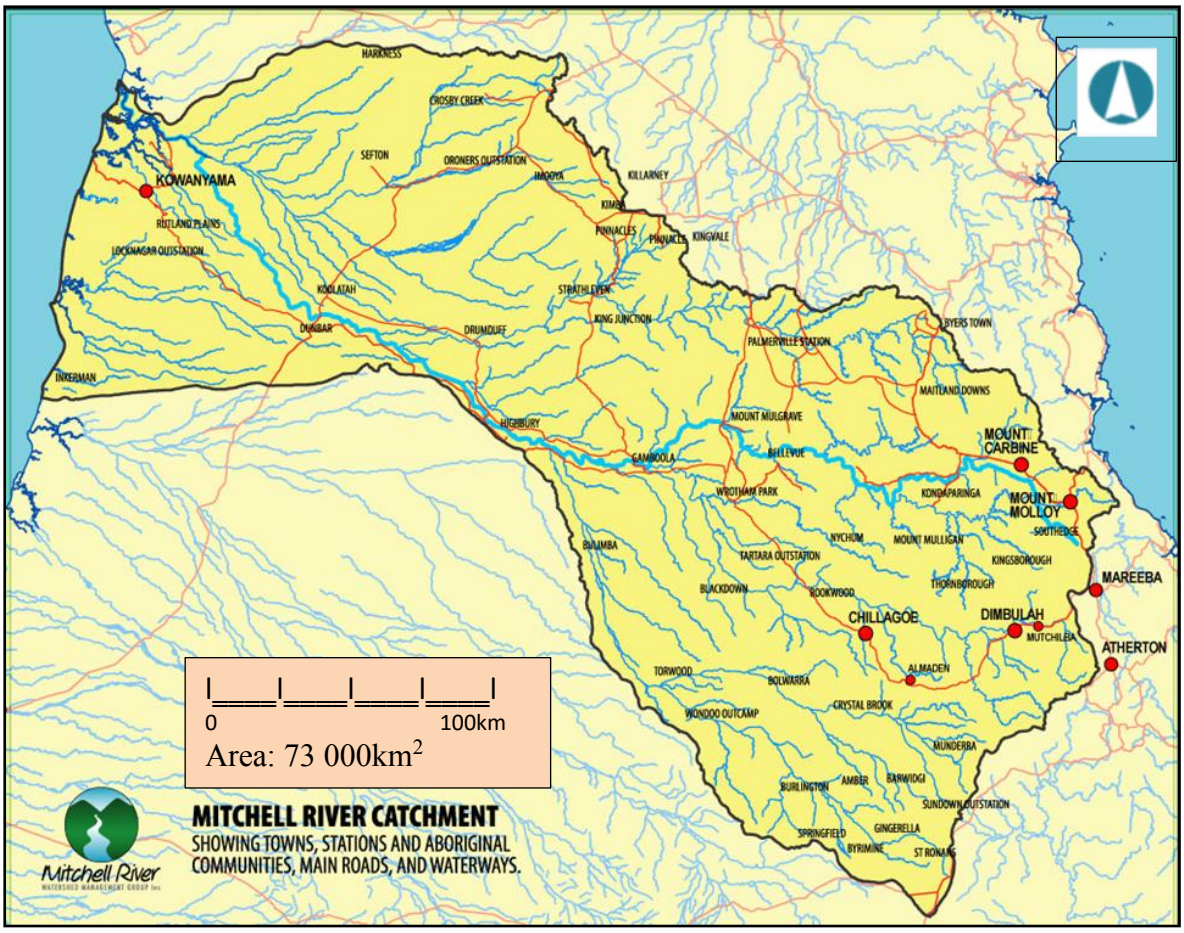


Figure 1 Mitchell River Catchment

(Source: MRWMG, 2014)

The Department of Climate Change Position Paper (2010) on adaptation to climate change in Australia recognised that the national interest could be met by a global emissions reduction consistent with stabilising greenhouse gases at 450 ppm CO_2 or lower. This would limit global warming to around 2 °C (p. 4). Their risk assessment process considered the contingencies required in Australia if global agreements on climate change management fail.

The need, therefore, is research into the effects climate change may have over a defined area or region (Wilby et al., 2006). The Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2014) has prepared possible scenarios over regions such as the

tropical savanna lands of northern Australia but comprehensive catchment wide studies are rare. This leads to the two questions that require explanation for this research. They are:
(1) Why has the Mitchell River catchment been selected as an area for study?
(2) Why focus a study on a geographical landform (in this case, a catchment)?

Firstly, the Mitchell River catchment is an underdeveloped catchment with a small population and has only been partially studied. Strategically located at the base of Cape York Peninsula, the catchment acts as the southern limit for the biodiversity of the Cape (Tropical Rivers and Coastal Knowledge ['TRaCK'], 2013). The Mitchell River catchment, due to its geography and location, is an appropriate region where the future impacts of climate change can be studied. The knowledge and skills gained can be applied across the wet and dry tropical zone globally. Uncertainty and the unknowable future (Howden, et.al., 2012, p. 42; CSIRO, 2014, p. 6) can be analysed and understood. Projections for policy and practice can be formed and advocated. Published research to date has focused on specific aspects of the climate and environment of the catchment. The need is for an integrated approach similar to the model Wilby et al. (2006, p. 204) have applied to gather catchment-wide data as climate change effects progress and impact. Importantly, integrated data and results gained from research on the Mitchell River catchment can be extended and applied to other catchments and enable a more cost effective and accurate model to be produced and implemented across tropical Australia as constructed by Howden et al. (2012, Table 3, p. 48).

To answer the second question, the concept of the Integrated River Basin Management (IRBM) is introduced as:

> *...the process of coordinating conservation, management and development of water,*

> *land and related resources across sectors within a given river basin in order to maximise the economic and social benefits derived from water resources in an equitable manner, while preserving and, where necessary, restoring freshwater ecosystems* (Global Water Partnership, Technical Advisory Committee, 2000, p. 5).

Because climate change is a global phenomenon and the: *'observed impacts of climate change have already affected agriculture, human health, ecosystems on land and in the oceans, water supplies, and some people's livelihoods'* (IPCC, 2014, p. 2), it is proposed that a holistic methodology is required to study the identified effects over the Mitchell River catchment to confirm the fact. Then, from a range of adaptation strategies, sustainable programs are selected to manage the effects.

1.2 Context or Statement of the Research Problem

The context chosen for this study is twofold. Firstly, to adapt to climate change, the population and environment of the catchment will by necessity adopt a community (self-determined) approach to sustainable, non-linear planning strategies. The default scenario is to adopt a linear, sectoral (externally-regulated) system (Thomalla, et.al., 2006, p. 46).

Secondly, to assist and enable the community to deliberate their choice of response is:
1. To formulate the mitigating climate-change strategies that the community are encouraged to adopt to plan, prepare and adapt, to a sustainable climate change scenario.
2. To develop suitable communication strategies designed to effectively deliver the findings to the catchment community and the wider stakeholder organisations e.g. governmental (Local, State and Federal), educational (Primary, Secondary and Tertiary), commercial (Financial, Logistical, Supplier, Mining and Producer organisations) and cultural.

This is, by necessity, a multidisciplinary research activity seeking to investigate some fundamental issues to which the target population and economy are exposed. For example, when confronted by climate change and its effects, what will be the adaptive responses the community members either choose or are required to make? Proven technologies are available should they decide to adopt them? The reaction from the community to these adaptive responses will form the perspective for this study.

A standard or indicator to assess the effects of climate change across the catchment needs to be selected for this study. Many markers exist (e.g. glacial retreat) but one indicator chosen for this study is derived by observing the seasonal variation in the nutritional value of the savanna across the catchment. The technology that graziers have already been encouraged to adopt (Queensland Department of Agriculture, Fisheries (DAF, 2014) is Faecal Near Infrared Spectroscopy (FNIRS). This has been developed for north Australian pastures by CSIRO. It is a cost-effective, accurate method able to provide data from across the catchment. This research project collected and collated this data widely sourced from the catchment. It has provided a baseline data set which, in future, will provide predictions, both for graziers and researchers. The effects of climate change, in this study, are derived from analysis of the assortment of native and introduced grasses and forbs grazed by cattle. The rationale for selecting this marker is:

(1) The grazing industry is widely distributed across the catchment and;

(2) Graziers continually need to monitor their herd's nutritional status and currently use a variety of traditional and modern indicators.

In summary, this research sought to determine as to whether FNIRS technology applied to the beef cattle herd of the Mitchell River catchment is a suitable, cost effective tool for

identification and quantification of changes in the environment of the catchment due to climate change. The research findings support this prediction.

1.3 Research Question

Within the context outlined above, the research question chosen was: how will the environment, population and economy of the Mitchell River catchment respond sustainably to climate change? Will the approach they choose, be either, community or sectoral? Or as in Giddens' (1984) "Structuration Theory" a combination of both?

This project endeavours to:

1. In consultation with stakeholders, design and implement sustainable climate change-adaptation strategies in preparing for, and adapting to, the effects on the population, economy and environment.
2. Develop an educational program to effectively deliver the findings to the residents of the catchment for their consideration and, hopefully, eventual adoption.

The research objectives are:

1. To understand the physical consequences of climate change
2. To recognise and quantify the environmental impacts of climate change.
3. To appreciate the cultural and economic effects of climate change on the community.
4. To design adaptation strategies to enhance the resilience of the community.

These objectives are to be achieved through my conduct of nine projects to:

1. Apply an understanding of the predicted impacts of climate change on the physical catchment into a future scenario of affects, e.g. temperature increase, rainfall variability, evaporation rates and climate generated disasters.

2. Create an evidence base to document the observed environmental changes resulting from climate change.

3. Determine the condition of the services residents have access to and identify needs that require attention.

4. Identify and develop climate change mitigation strategies the community may choose to incorporate into their adaptation strategy.

5. Encourage residents to develop their own mitigation strategies for future adoption.

6. Identify vulnerabilities that may inhibit the development of resilience and assign priorities and/or strategies for their implementation.

7. Develop and modify climate change mitigation strategies to be proposed to the community for their adoption.

8. Select a climate change indicator, practical in application and useful for the beef producers who are the significant commercial enterprises of the catchment.

9. Conduct a FNIRS baseline study of the grazing herd of the catchment.

The research goal is to investigate the possibility that residents of the Mitchell River catchment region may adopt a Giddens (1984) 'structuration' style community-based response to the issue of climate change.

1.4 Research Rationale

Anthropogenic processes and substances have created an increase in energy of the climate thereby driving environmental change (IPCC, 2013, p. 11). The long term effects of the change in climate on the environment, human population and economy of Australia are predicted to be significant, long term, and severe (Department of Climate Change, 2010, p. 4). As a consequence, it will affect the economy, human activities and settlement patterns of the region, including the Mitchell River catchment. Physical impacts on the tropical region

are believed to be more severe weather and increasing variability within the cycle. Ecosystems are expected to adapt through variations in plant and animal introduction, distribution and fecundity (i.e., soil characteristics, salinity, structure, transpiration and fertility). Impacts on the region's human population will be: economic, community health, community capital and settlement patterns (Duff, Garnett, Gerritsen, & Woinarski, 2008; IPCC, 2014, p. 2; Queensland Government- Climate Report–Ch. 5, 2012). Action to mitigate the issue of anthropogenic climate change has experienced difficulties since the suite of knowledge and practical sets required are contrary to the established systems: *'...because it cuts right across the demarcations of scientific disciplines and sectorally focused government departments'* (Fünfgeld & McEvoy, 2012, p. 324).

The grave nature of this scenario has created an imperative for this project, which is to ascertain the response required to mitigate human and physical vulnerability across the Mitchell River catchment. This rationale provides the means for understanding emerging issues as climate change affects the catchment. Research allows for the determination of the perceived and observed effects on the catchment and provides data to support the CSIRO predictions of future climate scenarios. The goal for the outcome is a plan and strategy directed to:

(1) manage adaptation to climate change in the catchment, and

(2) utilise skills, knowledge and abilities of the population to prepare a response to impending environmental threats (Cutter & Finch, 2008).

1.5 Outline of Content

This catchment study comprises seven chapters, including this one. Chapter 2 is a review of the literature that relates to the climate change phenomenon and reviews the

published literature relating to the geography, economy, demography, climate and climate change scenarios with its predicted impacts. This chapter was designed to gain knowledge of the imperatives driving the adaptation process at the catchment level and therefore by extension understand climate change adaptation in other north Australian catchments and communities. The review revealed that exposure to climate change could affect the human and physical environment of the catchment. Consequently, disaster management literature allowed the development of the theories and strategies. Literature concerned with instruction on the technology to determine the selected climate change indicator of the nutritional value of pasture across the catchment was reviewed.

Chater 3 is a description of the physical, social and economic characteristics of the catchment. Because the catchment spans five biogeographical regions, information is supplied on precipation, climate, soil type, and vegetation type and cover. Information is presented describing the impacts climate change is predicted to have over the catchment.

Chapter 4 discusses the methodology used for the study. Here the theories applied to determine results from both the quantative and qualititave analyses are presented, which are then synthesised into findings and recommendations for adaptation to an uncertain future. Data for the analyses were sourced from the literature review and census, semi-structured and unstructured interviews, on site observation and an analysis of 240 cattle faecal samples. Constraints on the scope and extent of the study are discussed.

Chapter 5 presents the results gained from the interviews, field survey and laboratory. The data were drawn from a wide range of sources representative of those issues identified as important in mitigating the impact of climate change. For example, issues surveyed include:

the pastoral industry, pastoral nutrition, natural resources, mining, infrastructure, economy, demography, education and community health. In addition, a strategy to mitigate the effects of climate change was investigated.

Chapter 6 discusses the results gained from the study. Here the qualitative and quantitative data are synthesised to form the mitigation strategies proposed to encourage and facilitate the adaptation of climate change. Included is a summary of the research project results, findings and recommendations on the identified climate change adaptation strategies, proposed for key sectors of the catchment. The emphasis is placed on sustainable planning and development options.

Chapter 7 includes a summary of the contribution made to the knowledge base on the Mitchell River catchment, as well as the topics identified for further study. The potential this research has for other catchments across northern Australia and by extension to similar environments worldwide is also presented.

Chapter 2

Literature Review

2.1 Introduction

This literature review investigates and critiques the published work on the topic of the impact of climate change on the Australian environment, economy and population. Then by extension, it is proposed to project the data as it relates to the environment of the Mitchell catchment. Because some climate change effects directly impact on the catchment population and environment, the disaster management literature will be reviewed to learn of the models and strategies necessary to sustainably mitigate the impacts. The aim is to provide strategies to help create resilient communities, infrastructure and environment. The review will investigate the technology applied to measure the selected climate change indicator (pastoral nutrition), and to investigate the wide range of technology available to observe the characteristics of the catchment.

2.2 Climate Change Impacts

The IPCC (Working Group II Report, 2014) reviewed data on the impacts, adaption and vulnerability of climate change. They sought to provide the evidence base to demonstrate the consistency between observed and modelled changes in climate change studies. The spatial accord between regional warming data and the global measurements was sufficient to conclude that:

> *…the effects of climate change are already occurring on all continents and across the oceans. The world, in many cases, is ill-prepared for risks from a changing climate. The report also concludes that there are opportunities to respond to such risks* (IPCC, 2014, p. 1).

The findings determined that both the natural and human environments display the effects of climate change, but non-climatic effects and adaptation influence the findings (IPCC, 2007, p. 4) (Figure 2).

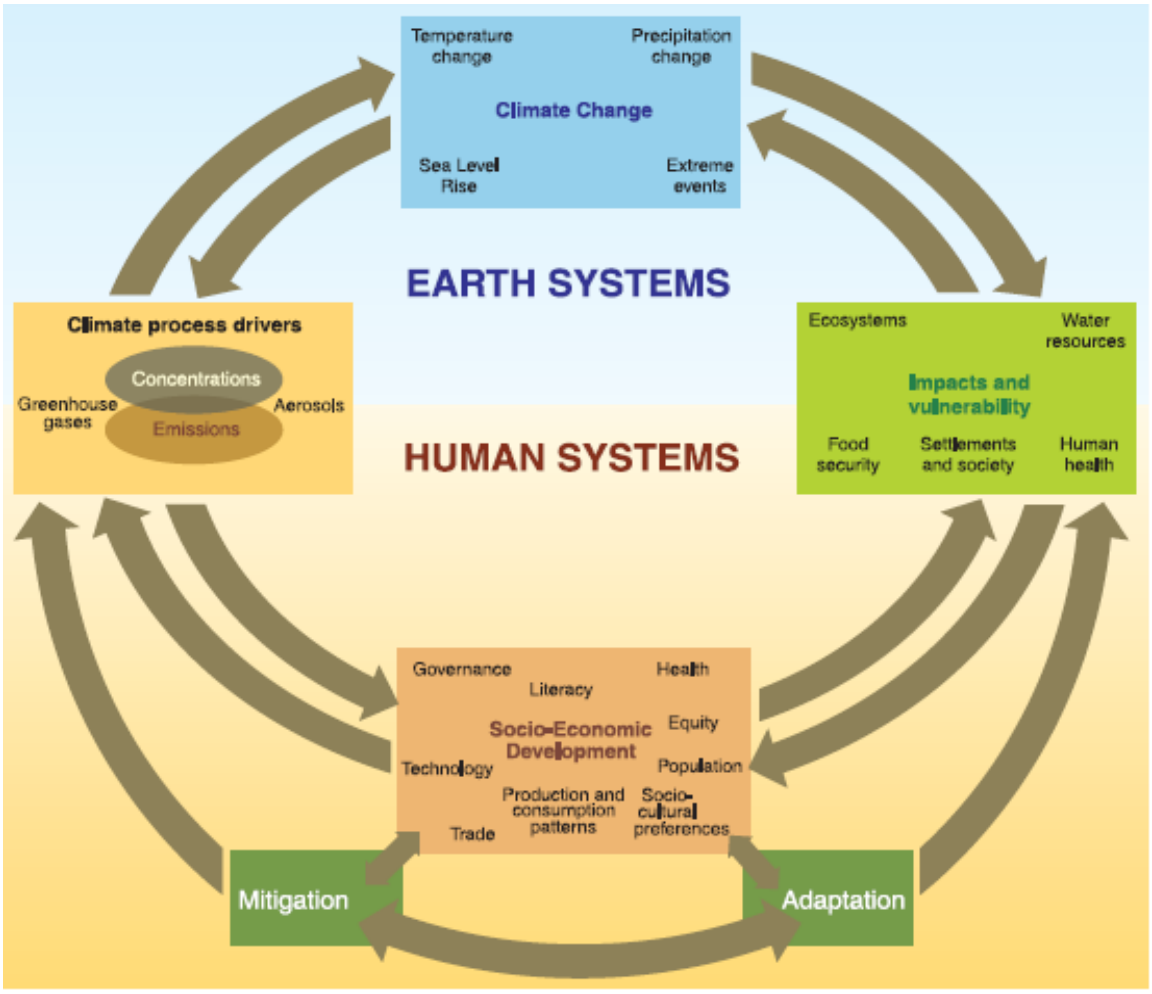


Figure 2 Schematic framework representing anthropogenic climate change drivers, impacts and responses
(Source: IPCC, 2007, p. 26).

The IPCC Twelfth Session of Working Group I (27 September, 2013) consolidated the previous work, stating that, of the last three decades, each has been warmer than any preceding decade since 1850. The report determined that:

> *The globally-averaged combined land and ocean surface temperature data, as calculated by a linear trend, shows a warming of 0.85 [0.65 to 1.06] °C over the period 1880–2012* (IPCC, 2013, p. 3).

> *Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system* (IPCC, 2013, p. 14).

To gain an understanding of the terms used in the literature, and as a guide for this work, the National Climate Change Adaptation Research Facility (NCCARF, 2014) has given the Australian definition for adaptation as*:*

> *Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation* (p. 1).

During the CSIRO Northern Australia Sustainable Yields Project (NASY, 2009), the research team studied the water regime changes occurring on the significant national environmental assets that are distributed across northern Australia. They modelled the high and low flow rates possible under four future climate and development scenarios, listed as:

- *Scenario A – Historical Climate and Current Development;*
- *Scenario B – Climate for the last 11 years and Current Development;*
- *Scenario C – 2030 Climate Change and Current Development; and*
- *Scenario D – 2030 Climate Change and 2030 Development of Farm Dams, Plantations, Groundwater Systems and Proposed Irrigation Development* (Summary IV).

These scenarios are derived from 15 global climate models, covering all possibilities. The team selected only the scenarios representative of the mid-range of possibilities, but all are relative to current conditions. This research is designed to estimate the impact climate

change has on the surface and groundwater supplies across northern Australia. A project conducted by McJannet et al., (2009, p. 51–52), considered a whole-of-region concept to determine the sustainable extraction rates on surface and sub-surface water flow from tropical rainforests of North Queensland. The parameters set are within climate variability and projected climate change rates. It utilises rainfall runoff models, groundwater recharge models, river system models and groundwater models. It also considers both connections between upstream and downstream and the surface-subsurface flows. One of the systems investigated was the Mitchell River. Their analysis was based on the historical predevelopment climate (Scenario A) above. Scenario B predicts little wet season change in mean flows, but under Scenario C (wet) the flow will increase 29% to 40% above the historical mean. Dry season flow is predicted to cease for a similar increase in duration. No analysis was conducted for Scenario D.

Part Two of the Position Paper on Climate Change Adaptation (Department of Climate Change, 2010, p. 11) outlines the strategy for implementing the Commonwealth's vision, which is applicable to all communities and all levels of government. The key message is that, because sectors will be affected at different times and in different ways, there is an imperative to identify some national adaptation priorities. The characteristic of climate change is that it will not be felt uniformly across Australia or at the same time across all sectors and regions. Although the nation needs to be prepared for adaptation, not all sectors or potential impacts need to be considered and planned for with the same degree of urgency.

An effective response to adaptation needs to identify and prioritise impacts requiring attention over the next five to ten years. It is considered that the Commonwealth's attention priorities need to be given to:

> *...the magnitude and timing of impacts on a particular area (informed by the IPCC and more recent analysis and assessments):*
>
> *• whether it's important to take early action to reduce or eliminate risks of locking in inefficient policies or investing in assets which have not factored in climate change risk; and*
>
> *• whether the matter is a Commonwealth responsibility or requires Commonwealth leadership to deliver a nationally consistent and/or effective outcome* (DCC, 2010, p. 11).

Based on analysis of these considerations, the Australian Government has identified the following as initial national priorities for adaptation action:

> • *coastal management;*
>
> • *water;*
>
> • *infrastructure;*
>
> • *natural systems of national significance;*
>
> • *prevention, preparedness, response and recovery with regard to natural disasters; and*
>
> • *agriculture* (DCC, 2010, p. 11).

Climate change is already affecting Australia's natural ecosystems, and given their sensitivity, natural systems of national significance, such as the Great Barrier Reef and Kakadu National Park, will require on-going priority attention. This National Climate Change Adaptation Research Plan identified the priority research areas needed to enhance the capacity of agricultural, freshwater aquaculture and forestry industries to adapt with their associated industries and organisations (DCC, 2010, p. 12).

Adaptation at the Queensland state level is directed at:

> *Providing information, building resilience and improving planning in Queensland. Queensland needs to adapt to climate change impacts that are already occurring and that will continue to occur despite action to reduce emissions. It's essential for Queensland to develop resilience within its communities and industries to adapt to the inevitable impacts of climate change* (Department of Environment and Heritage. Climate Q: Toward a Greener Queensland, 2009, p. 4).

2.3 Remote Sensing and Climate Change

Tracking climate change in the environment has been measured and modelled by CSIRO and the Australian Collaborative Rangeland Information System (ACRIS). Some of their projects include: land clearing; effects of grazing by domestic, feral and native animals. Their other projects observed the impact of introduced exotic plants and animals, the use of fire and wildfires; and seasonality and variability in climate. Another of their initiatives to track changes to the rangeland environment is the Australian Grassland and Rangeland Assessment by Spatial Simulation project, otherwise known as 'Aussie Grass'. Additionally, The Bureau of Meteorology (BOM) supplies the Normalised Difference Vegetation Index (NDVI). These grids and maps are determined from satellite data and provide a measure of the amount of live green vegetation and a summary of the status and dynamics of Australian vegetation. The satellite data is sourced from Advanced Very High Resolution Radiometer (AVHRR) on board the National Oceanic and Atmospheric Administration (NOAA) satellites (McKeon et al., 2009).

NAFI utilises remote sensing technology to provide current and historical information on fire activity across the northern Australia. This information not only provides the scale of

the fire, but also the timing and ignition point.

The Kowanyama Aboriginal Land and Natural Resources Management Office utilises this technology to develop and implement a fire management program, covering all their traditional and pastoral land management. This fire management program engages traditional owners to integrate fire management into the weed management plan for the National Parks and is a potential climate change mitigating strategy. Remote sensing of weed infestations along roads and power line corridors of the Wet tropics in the Cairns region were studied by Goosem and Turton (2006). They sought to determine whether remote sensing could discriminate and identify weed species growing along the power lines. Airborne Data and Acquisition and Registration (ADAR) had great potential for the task, but were limited by poor camera performance. Ikonos satellite data provided quality results but was limited in spatial analysis of weeds due to its resolution characteristics. Brooks et al. (2008, p. 225) utilised both current and historical remote sensing data to quantify sediment yield and scarp retreat across the Mitchell River catchment to provide planners with erosion information prior to any intensive land and water development on the catchment. These data are also critical in predicting effects from climate change. This research project utilised a range of remote sensing technology to provide data. The NAFI (Figures 3, 4, and 5) utilises a range of remote sensing satellite data to map active and historical fire activity across the catchment. A significant potential of this service is to predict future climate change induced bushfire conditions. (These fire information figures are referred to in later chapters).

Cloud cover data over elevated range of the Wet Tropics is utilised to determine the cloud harvesting rates of the cloud forests at risk from the effects of climate change.

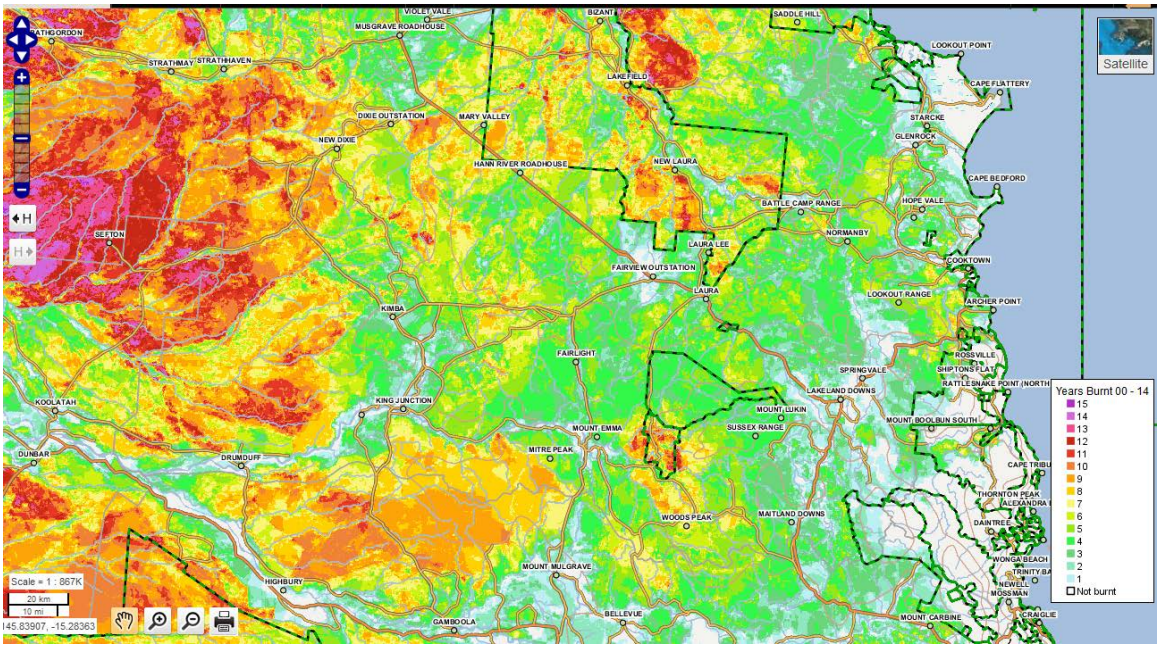


Figure 3 Fire History up to 2015

(Source: NAFI)

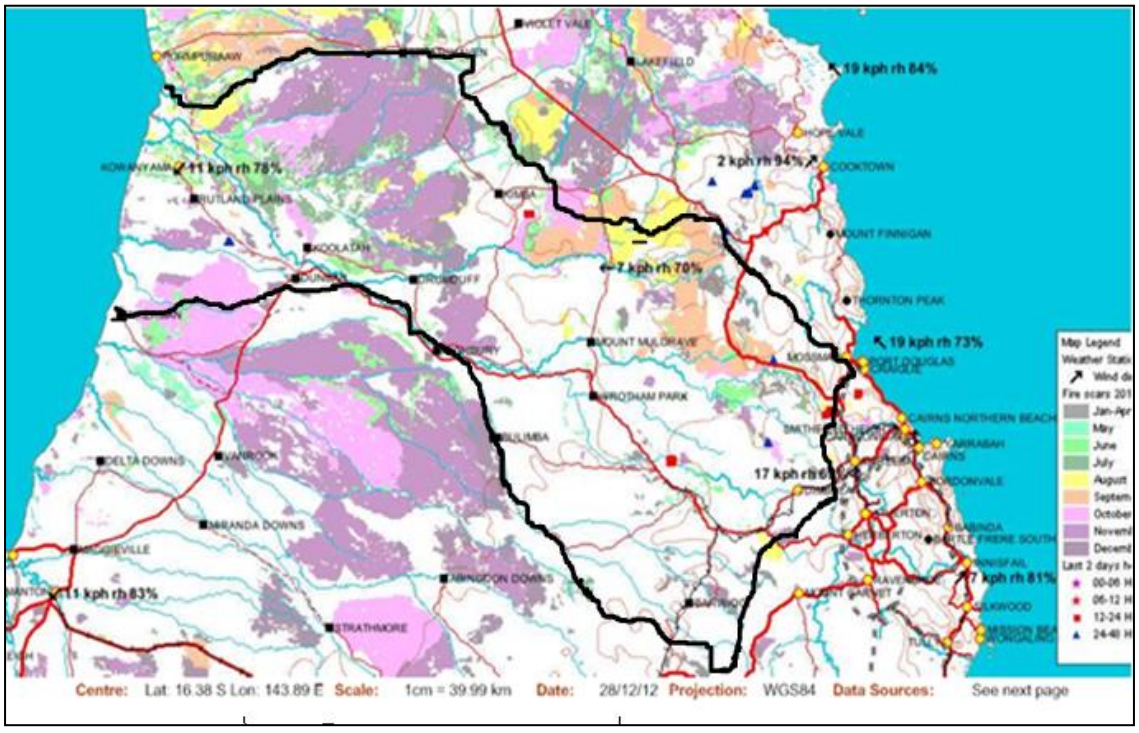


Figure 4 Fire Disaster History for 2012

(Source: NAFI)

Foot note: Figures 3, 4 & 5 illustrate the impact of seasonal burning across the catchment. Note the late season fires on the Palmer River mining reserve attributed to metal detecting (MRWMG). Figure 4 illustrates the fire disaster Oct.-Nov. 2012 across the Gulf Region.

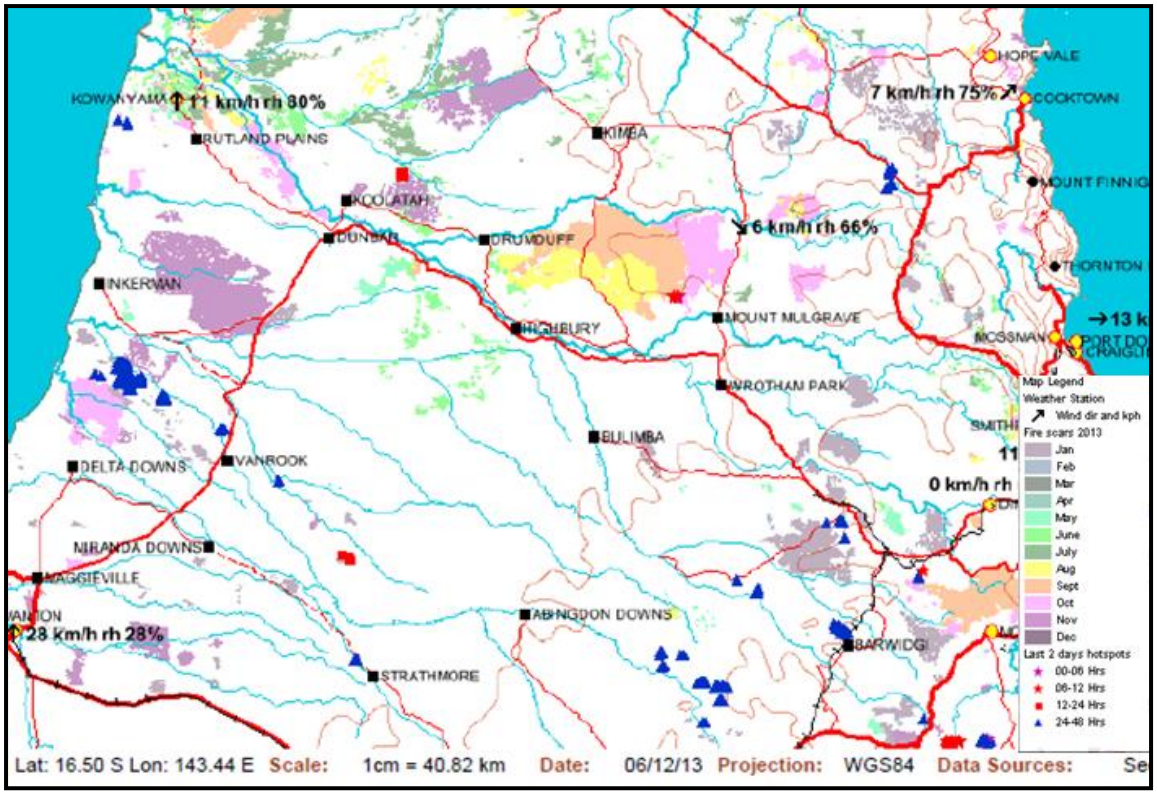


Figure 5 Fire History to 6 December 2013

(Source: NAFI)

2.4 Disaster Management

Disaster or hazard management is a crucial element of climate change that requires mitigation of vulnerability as well as enhancement of resilience and adaptive capacity in the community.

> *Understanding that climate change is a challenge in managing risk opens a wide range of opportunities for integrating adaptation with economic and social development and with initiatives to limit future warming* (Field, 2014, p. 1).

The IPCC - Working Group 1 (2013) raises concerns that are significant for issues across the Mitchell River catchment:

> *Observed changes in the Climate System: Warming of the climate system is unequivocal, and since the 1950's, many of the observed changes are unprecedented*

> *over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased* (IPCC, 2013, p. 2*).*

A reason for the decision for understanding climate change to be considered in terms of disaster management is the *'uncertain and unknowable future'* (Howden, 2008, p. 24; NCCARF, 2014). Paton (2005, p. 3) suggests the reality of advantages and disadvantages of a disaster experience are evident and quantifiable, but growth and loss results are projected along differing sets of variables. Self-efficacy is a term used by Paton (2005, p. 4) to describe how people think, feel and behave within their own capability. He suggests that, as an individual grows in self-efficacy, their adaptive capacity increases. That study proposes, in regard to disaster loss and disaster growth, that risk management needs to consider that each of the outcomes emerge from a distinct set of variables. Figure 6 suggests the means by which risk management can be subdivided into paths that consider variables of resilience and vulnerability and their effect on the outcomes of a disaster.

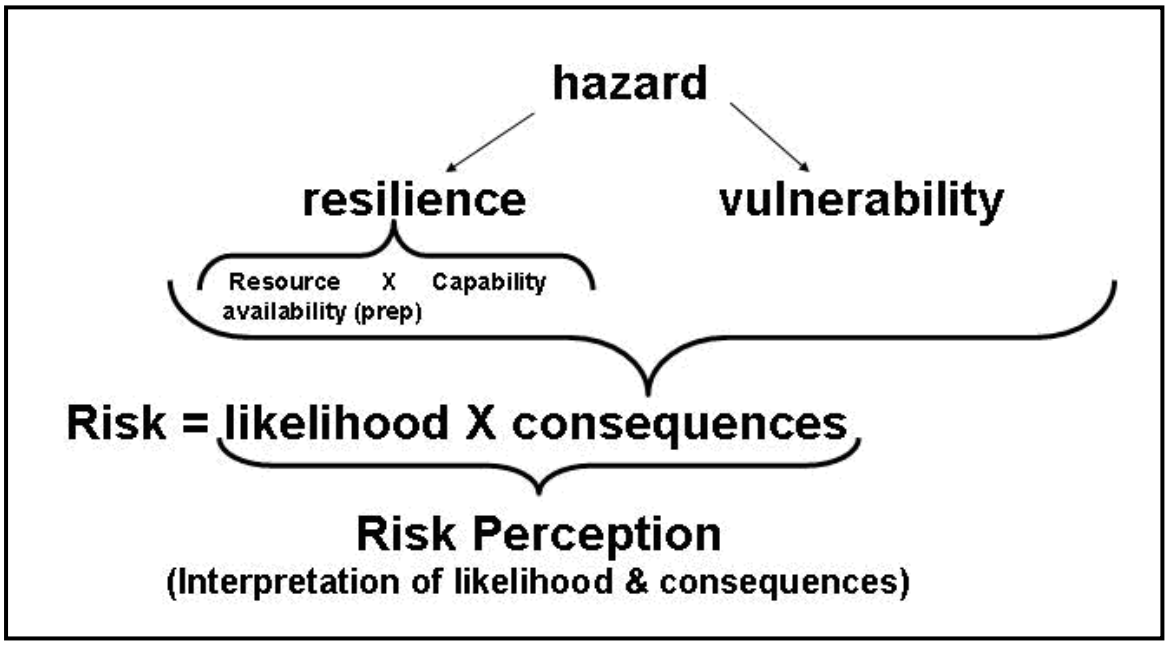


Figure 6 Relationship between risk, resilience and vulnerability
(Source: Paton, 2005, p. 4).

This current study identified hazards within the Mitchell River catchment as including climate variation (CSIRO-BOM, 2012), health (IPCC, 2014, pp. 6, 14), bushfires (NAFI, 2014), cyclones (CSIRO-BOM, 2014), flood, chemical pollution of waterways (MRWMG, 2013), erosion and siltation (Brooks et al., 2009; Shellberg, 2012), pest weeds, feral animals and unauthorised human activity (MRWMG, 2014). Within a community, consequences from a hazard (Figure 6) are the result of interaction between the hazard, physical characteristics and personal and community features that create a predisposition to loss from the hazard and thus increase vulnerability. This contrasts with those features that initiate a response to increase resilience to adapt or cope. Therefore, risk management roles are decisions and actions directed to reducing vulnerability and building adaption and resilience.

Cottrell and King (2012, p. 154) apply experiential analysis from previous disaster events to prepare future planning and preparedness guidelines. This strategy is designed to minimise community vulnerability to an event and improve future resilience. They summarised recent global disaster events and determined that, in a disaster, immediate impacts include death, injuries, structural and infrastructure damage and material loss.

Immediately following a disaster, researchers begin the process of recording and documenting the event. King (2000) catalogues this analysis into four types:

(1) Analysis by emergency services to manage and prioritise logistics and resources.

(2) Physical and environmental analysis conducted by physical scientists and engineering specialists to determine recommendations to mitigate immediate and future events.

(3) Social impacts, recording community preparedness, response, awareness and behaviour.

(4) Psychological and medical effects determined for triage and longitudinal management of community health and welfare.

This process is planned to provide information for emergency services planners to enable preparedness for future disasters, created in whole or part by climate change. Management of a disaster does not conclude with risk management but is incorporated within the topics of community, preparation, vulnerability, resilience and adaptation, which are the subjects for discussion in the following sections.

2.4.1 Community

Climate change adaptation requires critical information on the change in weather and climate extremes, IPCC (2013, p. 2), to inform policy makers on risk management. The IPCC (2014, sect. 11.7.2) commenting on climate change health adaption risk, considers the communities with "*high levels of social capital*" are most suitable for progressing health specific information to respond to climate change impacts. The definition of community adopted for this research from the diverse literature is best defined by the New Zealand Ministry of Civil Defence and Emergency Management (2010) who submit that community is:

> *…a social, religious, occupational or other group sharing common characteristics or interests and perceived or perceiving itself as distinct in some respect from the larger society within which it exists* (p. 6).

When thinking about engagement, it is useful to look at communities as two distinct types; communities of place and communities of interest. The question is, what is a community and what are the implications for hazard studies and practice?*'*

To answer this question, Cottrell (2007) defined the history of '*community*' as a geographical concept. Citing Toennies (1887) and his (ideal) community types, Gemeinschaft and Gesellschaft, these differentiate between groups held together by

common ties and feelings (i.e. intrinsic value) and organisations that integrate roles around instrumental objectives (i.e. means to specific ends). To demonstrate the scope of the '*community*' question, Bell and Newby (1972, pp. 28–29) collated and studied 94 identified definitions of community. Definitions comprehensively cover a plethora of social, ecological and psychological notions and concepts.

The notions of moral (worth) and empirical (objective) community are discussed primarily considering Nisbet (1970), Bell and Newby (1972) and Wellman's (1988) work. Buckle (1998, p. 21), considering the community's definition in context of most risk management activities, states: *'By community, I mean any grouping of people that have something in common, something to share (and believing that they have something in common and having only that as a communal attribute may be sufficient to define a community)'.*

2.4.2 Preparation in a Community

McLachlan (2007) comments on the preparedness of Wellesley Islands' inhabitants, in an area of the Gulf of Carpentaria which, like Kowanyama, is noted for frequent cyclone activity. Today, modern reinforced-concrete block-constructed houses withstand cyclonic events and provide good shelter for inhabitants (p. 148). Communications have improved and, with a robust electricity supply, resistant to cyclones, residents have continuous electricity, radio and television throughout the event (p. 151).

Oral history of northern Australian hazards from a traditional perspective shows the incorporation of the myths, legends and law relating to natural disasters, which are suggested to extend back in time thousands of years (McLachlan, 2007, p. 145). This cultural knowledge is intrinsic to indigenous peoples' perception and preparation for a

disaster. The question proposed is whether such knowledge is applicable to modern disaster management. McLachlan (2007) explained traditional methodology and practice, identifying awareness techniques indigenous people apply in reading weather, as well as other natural indicators that forecast possible disaster:

1. In coastal areas, an abundance of ants and cockroaches, together with changes in plants and flowers indicate the onset of the annual wet season.
2. A potential severe storm or cyclone is traditionally forecast by the combination of hot humid weather, warmer sea water temperatures, higher than normal tides with a change in sea colour. Other indicators are crocodiles building nests higher up and with birds moving away from an area.
3. In all communities, a ring around the moon and the interaction of cloud movements and prevailing winds are indicators that weather changes are imminent (p. 145).

The technology in constructing various types of their traditional cyclone shelters used cane grass bent over, woven and looking like a giant anthill (p. 147), but large enough to accommodate four to five families. Another is a small shelter constructed from special cane grass. A third method is on a hill, away from wind, comprising a dug depression under a framework of sticks covered with paper bark. As the storm approached, inhabitants lay on their back, covering the bark with sand and remaining inside until the storm has passed, then emerged intact. These communities had clear plans and preparations for natural hazards.

A prepared community, described by the Insurance Council of Australia (2008), has:

1. Well-rehearsed and proficient emergency plans.
2. Building design and systems that adapt to local hazards and risks.
3. Hazard reduction processes during low risk periods.

4. Community-wide adoption of personal and business insurance strategies appropriate for particular risk analysis.

Keogh et al. (2011) give an example of a prepared community in describing the situation in Charleville, Queensland during the 2008 and 2010 floods. Their study sought to investigate community levels of vulnerability, resilience and adaptive capacity. Their key research finding was a community belief that they had a personal responsibility to prepare for and develop strategies to mitigate in a disaster event. This belief led to individual and community actions that contributed substantially to their response and adaptation to the impact of those floods.

The research team determined that, compared with other flood events, Charleville's resilience was founded on two criteria:

(1) High levels of organisation and cooperation.

(2) Enduring established and operational official and social networks.

This level of confidence is demonstrated by the community's enduring commitment to remain in town regardless of impending or recurring flooding. Because Charleville's experience was due to the high intensity rainfall dispersed over a disproportionally small area (a predicted climate change phenomenon), community preparedness in future, according to Keogh et.al. (2011) will need to allow for this. The paper's conclusion gave implications for Australia and internationally: *'Charleville was found to be a useful model of climate change adaptation and how towns facing natural disasters should organise and operate'* (p. 719).

McLennan et al. (2011) provide a good example of a prepared community in the face of a bushfire, which swept through the Lake Clifton area, in south-west Western Australia in 2011. Ten homes were destroyed, considerable damage to vehicles, outbuildings and livestock followed, yet without any loss of human life. Community preparedness was illustrated, although most respondents reported not having had previous experience with bushfire. They had read the emergency services preparedness material and were aware of their community's fire risk. They prepared and implemented their own household plans. This effectiveness was reiterated when most respondents indicated they would adhere to that plan again should the emergency reoccur. All were insured, although some admitted to being underinsured. Assistance by family and friends, supplemented with current information on the fire front, contributed to survival, with those evacuating assembling at a central defended community point. An important observation is that respondents were generally aware of the bushfire hazard in the area. The study demonstrated the need for individual instruction and assistance on the range of actions designed to reduce specific threats to life and property. The household bushfire plan was observed to be the major determinant of action and therefore McLennan et al. (2011) recommended that emergency services provide educational material to enable residents to prepare their own household plan. Another significant finding from respondents' submissions was that their sources of information concerning the fire, which initiated their awareness response, were made from a combination of the wide range of sources; 83% visual cues (i.e. smoke and/or flames), 65% phone calls from family/friends, 13% emergency services personal contact, 8% internet, 8% residents phoning authorities and 3% television broadcasts (contacts shown as percentages are not mutually exclusive). This research reveals supporting evidence that social networking such as Facebook and Twitter play an increasingly important role in providing

information prior to and during a hazard. In summary, valuable insights this research has utilised and made applicable to climate change are:

1. In a prepared community, traditional knowledge, experience, awareness and preparedness for disaster is required.
2. In a built environment, preparedness planning with construction systems use proven and tested materials and systems to isolate the hazard and thereby provide resilience.
3. There are well-rehearsed and trusted information systems, emergency plans, procedures and practices at an individual/household, community and organisational level.
4. Hazard reduction and mitigation strategies and plans, coupled with suitable personal and business insurance policies enhance the resilience and reduce the vulnerability of the community.
5. Development of integrated social networks supports confidence, trust and resilience both in the individual and their community.

The literature has provided evidence of the properties and dynamics of a prepared community and coupled with the predictions CSIRO-BOM (2014) present for the climate change scenario in the region an assessment is proposed that the Mitchell River communities have, by necessity, developed considerable resilience to disaster, specific to each community NGRMG, (2015, pp. 53-55).

2.5 Vulnerability

The residents and communities of the Mitchell River catchment live in a remote and isolated area. This may expose them to be **vulnerable** to disaster events that are predicted to increase under climate change (IPCC, 2014, p. 1). Buckle (1999, p. 23) states: *'By vulnerability, I mean a propensity to loss'.* He qualifies this statement with his

understanding and concept of ***'differential vulnerability'*** i.e. various people and groups may be exposed to different types of loss. Phillips and Hearn (2007, pp. 61–70) determined, from their research of recent tsunamis, earthquakes and hurricanes, that most victims were women, children, elderly, disabled and the disadvantaged. Importantly, Buckle (1999) includes with vulnerability its partner, which is the much more complex concept of **resilience**: '*which I take to be the capacity to withstand damage or to recover from a loss'* (p. 23).

Paton (2005, pp. 3–4) identified a series of **psychological predictors**, which include negative traits of personality and/or attitudinal factors, such as denial-based coping, learned helplessness or immaturity as indicators of individual vulnerability. **Group vulnerability** is the term which describes those demographic variables and prevailing socio-economic environmental characteristics to the individual or group. Unfortunately, the reality of any increased vulnerability in these groups necessarily includes them as a fixed factor in the risk equation and social policy agenda, thus acting to increase these individuals and groups potential loss from disaster. These variables may, in turn, be countered by factors that act to increase adaptive capacity in a crisis. Paton (2005, pp. 4–5) considers that such variables do not in fact reduce vulnerability, but rather act independently. The example given is that some community individuals may exhibit psychosocial resources, enabling a capacity for adaptation not apparent in their cultural/peer group.

Morgan (2011, pp. 1–4) summarised the characteristic culture of Australian rural communities as having psychological capacity to cope with chronic stressors of the >12-year drought, followed by the acute stress of recent floods. Primary producers and rural people are noted for their independence, resilience and ability to '*get the job done and done*

properly'. Morgan (2011) studied a rural community affected by flood, where a resident described the situation thus:

> *It was a bit like the effect on the landscape of a bushfire going through the place, leaving everything, including houses, standing, but all grass and vegetation destroyed. The land was covered with black and brown mud and smelt of rotting vegetation and rotting possessions* (p. 3).

Nevertheless, many producers benefited from the flood disaster by reporting record levels of production at harvest. The community studied was reported to show high level characteristics of a strong resilient community. Regardless, health care workers are aware that reactions to emotional stress may be delayed or deferred until well after the event. However, some Australian primary producers are reported by Morgan (2011, p. 3) to be tiring. It is believed to be the cumulative levels of stress from financial matters, mandatory compliance and a range of imposed regulations. Beef producers are suffering from price and profit stagnation for the past 12 years, increased debt and return on investment of <1% (Meat and Livestock Australia [MLA], 2014). Market prices and access to resources are all issues potentially affecting the mental health of this group.

Haikerwal (2011, p. 2) also cites Warren Bennis, whose comments are based on personal experience:

> *The leaders I met, whatever walk of life they were from, whatever institutions they were presiding over, always referred back to the same failure, something that happened to them that was personally difficult, even traumatic; something that made them feel that desperate sense of hitting bottom; as something they thought was*

almost a necessity. It's as if, at that moment, iron entered their soul; that moment created the resilience that leaders need.

Community vulnerability is formed on the concept of a disaster being a: *'function of the human population that resides in the area impacted'*. (Anderson-Berry 2003, p. 211), Buckle et al. (2000), Cannon (1994 and 2000), and Cutter (2003) argue that the attribute which transitions a community or individual's experience to a disaster is its vulnerability. Blaikie et al. (1994) determine this to be a dynamic process, a function of the aggregation of individual, group and cultural relationships. When they consider this combination of relationships, then synthesise information and react to the hazard's impact, the recovery process can then commence. Variables of community resilience and vulnerability may include:

• societal structures, infrastructure and institutions, including physical structure integrity;

• community processes and structures such as community organisation, mobility of households, community cohesiveness and the social support this affords; and

• demographics and other characteristics of individuals within the community, such as age, ethnicity, education and wealth (Fothergill, 1996; Fothergill et al., 1999; Buckle, 1999, and Cannon, 2000, p. 211).

An example demonstrating the community response behaviour is from a survey by Anderson-Berry (2003, p. 229) following the experience of a cyclone in Cairns, North Queensland. It revealed, at that time, that the awareness education program had achieved limited success in increasing individual and community preparedness due to the educator's focus on information promotion and their failure to communicate risk.

Global response to the issue of vulnerability is contained in the final document of the World Conference on Disaster Reduction (Hyogo Framework for Action, 2005–2015), which suggests that there is an international need to promote strategic and systematic approaches to reducing vulnerabilities and risks to hazards (United Nations [UN], 2005). This declaration points out that:

> *The starting point for reducing disaster risk and promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge* (UN, 2005, p. 7).

Birkmann (2006) also conducted a vulnerability survey on a global scale (Figure 7). The concept is expanded from that of personal experience to an international vulnerability hierarchy. He suggests it is better to observe disasters as a complex of interactions between the physical event and the affected society's vulnerabilities. This value is determined by its aggregate of human behaviours. Using this thesis, it follows that: *'the promotion of disaster-resilient societies requires a paradigm shift away from the primary focus on natural hazards and their quantification towards the identification, assessment and ranking of various vulnerabilities'* (p. 10).

Birkmann's (2006, p. 10) opinion promotes vulnerability indicators as 'key activities', in that the goal is to: *'Develop systems of indicators of disaster risk and vulnerability at national and sub-national scales that will enable decision makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to decision makers, the public and populations at risk."* (UN, 2005, p. 7) This is best

summarised in Figure 7 below, which contains characteristic spheres showing the concept, yet allows further development of individual vulnerabilities:

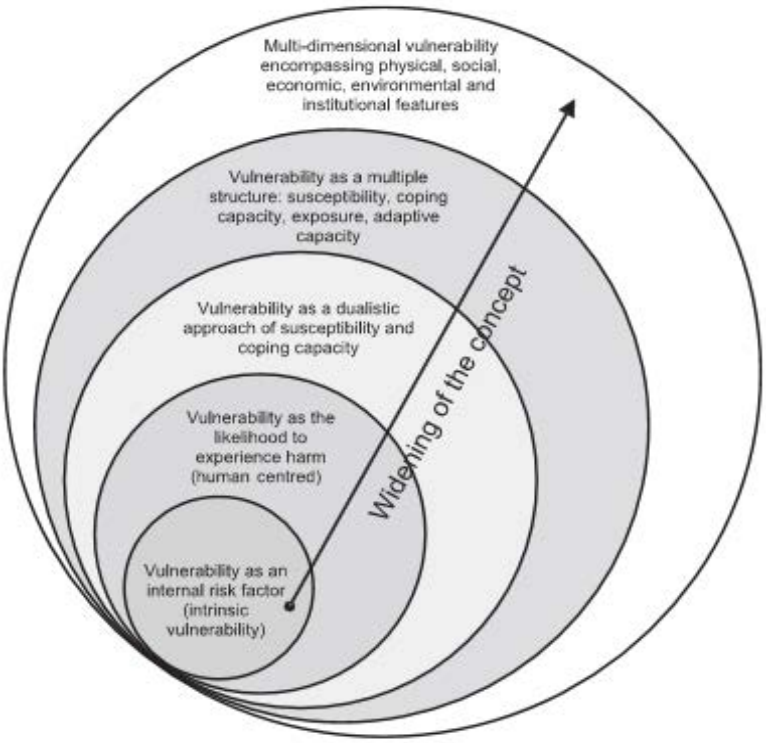


Figure 7 Vulnerability concept
(Source: Birkmann, 2006, p. 17)

Birkmann's (2006) analysis proceeds through these themes in the diagram. The conclusion he makes is that *'intra and intergenerational justice*' (p. 43) is the key principal for vulnerability reduction. Concepts such as socio-political organisation, environmental degradation, resource limitations, export of risk and sustainable development are but a few that impact individually or collectively on communities and nations' exposure to vulnerability. In summary is a call to the global community to: '*recognise the fact that the social and the economic are closely linked with the environmental sphere*' (p. 43).

2.5.1 Social Vulnerability

Bara (2010, p. 3) applied this term to the Titanic disaster metaphor in order to demonstrate how passengers' vulnerabilities were defined by class. All first and second-class children survived. One in three third class children survived. Of 1800 victims of Hurricane Katrina, clearly the disadvantaged suffered most, i.e. almost half were 75 years and older (Bara, 2010, p. 2). Nursing homes had inadequate plans and resources for evacuation. Social vulnerability as opposed to natural or environmental vulnerability is defined by Blaikie et al. (figure 8, 1994) as:

> *…the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or society* (p. 11).

This illustrates characteristics of social vulnerability and Bara (2010, p. 4) highlights these by:

1) *Defining an attribute of persons or groups and points to differences within societies;*
2) *Emphasizing a process of understanding vulnerability and embeds this in the disaster-management cycle of Prevention and Mitigation, Preparedness, Response and Recovery;*
3) *Including capacity, i.e. everyone has some capacity so anticipate, cope, resist and recover.*
4) *Emphasizing that vulnerability is a matter of degree, not an absolute quality;*

5) *Pointing to the fact that vulnerability is determined by a combination of several factors;*
6) *Acknowledging that, not only life itself, but livelihoods are at risk, thus shifting the focus away from 'fatalities' as the single dominant measure of disaster impact;*
7) *Extending the threat spectrum to events that originate both in nature and in society* (p. 4).

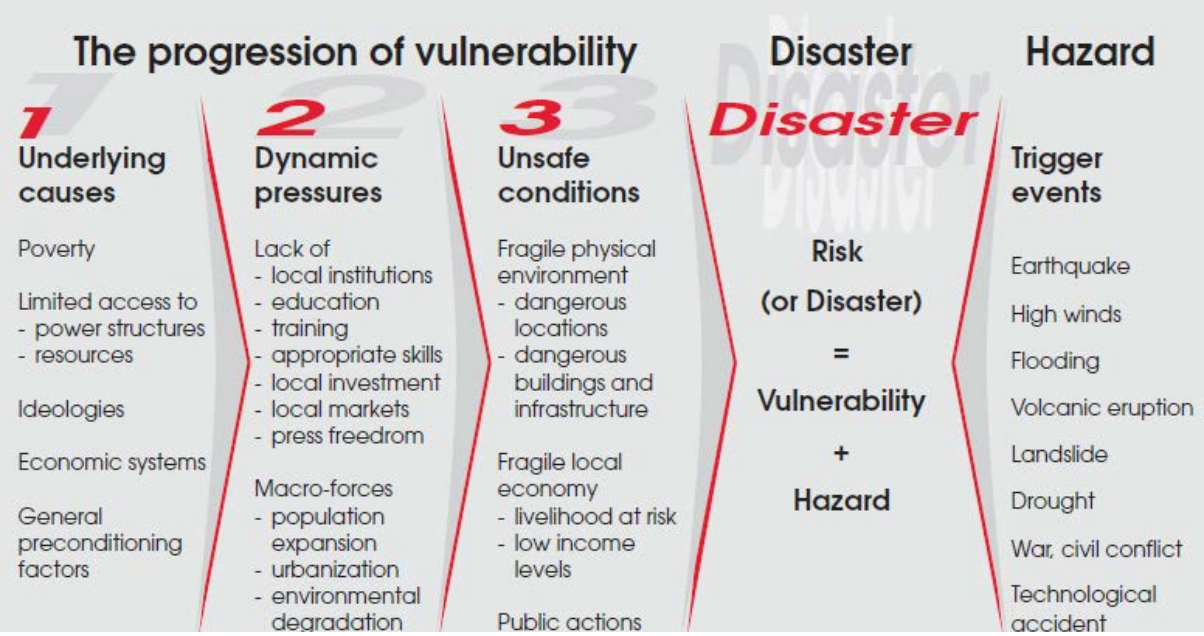


Figure 8 Disasters as a combination of hazards and vulnerabilities
(Source: Blaikie et al., 1994, p. 51)

The group vulnerability concept is concerned with those target groups conveniently identified by emergency services as qualifying for vulnerability reduction strategies. These may be children, the elderly, poor or the homeless. Unfortunately, this superficial approach fails to identify affected individuals who either fall through the gap between groups or belong to more than one of them.

No discussion on climate change impacting human populations within the Mitchell River catchment is complete without due consideration of social and legal impacts. Disaster

management literature, e.g. Birkmann (2006), Buckle et al. (2000), Bara (2010), Blaikie et al. (1994), Paton (2005, p. 4), and Phillips et al. (2007) determine the characteristics of those vulnerable to disaster. A summation of this literature is that those individuals mostly affected are those with social, economic and physical disadvantage (Figure 8).

One response for these vulnerable groups lay within the concept of climate justice, which coordinates human rights and development to consider the most vulnerable populations and assist with the impacts of climate change. The proponents of this concept promote that: *"Climate justice is informed by science, responds to science and acknowledges the need for equitable stewardship of the world's resources"* (Robinson, 2011, p. 1).

Another dimension to the discussion on social vulnerability is the work of Ellemor (2005). Her research on emergency management in remote indigenous communities suggests that the nationally accepted process of Emergency Risk Management (ERM) is based on the consideration of individual and community vulnerability. However, it may not be as effective or as relevant in managing risk in some indigenous communities. This is due to the unique cultural understanding of the components of risk and hazards within a remote community. Accepting the values, experience and the capacity of indigenous local communities to develop a working relationship, and practice, will in turn help to manage disasters and develop resilience. The author, relating to experience gained from observing public and private institutions working with indigenous people, suggests that an effective strategy is to accept their existing and prevailing capacity. The result should be that their values and relationships will in turn develop into strategies and ways of working toward change. Ellemor (2005) then continues with the Australian experience, whereby governments have actively promoted the indigenous outstation movement across northern Australia. Often these are in remote locations, but existing emergency management

structures mostly relate to the main settlement. The survey from this study (Appendix C) revealed that the Kowanyama community does not have an ambulance to treat and transfer patients from its remote outstations. Emergency patient transfer is instead via any available vehicle.

European colonial culture has established the discourse of indigenous powerlessness, which is then further compounded within the vulnerability concept. Emergency management within these indigenous communities is encouraged to reject the belief that weak, marginal and passive communities require the imposition of external change to emergency management by outside experts (Ellemor, 2005, pp. 6–7).

Skertchly and Skertchly (2000) record the variation and dissonance between indigenous and western, (modern) philosophy in interpreting and understanding the environment (Table 1).

Table 1 Characteristics of modern and Aboriginal cultures

FEATURE	MODERN	ABORIGINAL
World view	Fragmented	Comprehensive
Land	Commodity	Living heartland
Being and living	Individualisation	Communitarian
Culture	Diverse	Cohesive
Natural environment	Detached/exploited	Integral/cherished
Resources	External dependency	Self sufficiency
Location	Fixed	Mobile on clan land
Natural hazards	Distant understanding	Detailed awareness
Emergency management	Few professionals, many volunteers	Total preparedness, mobility and change
Values/Spirituality	Shifting	Enduring

(Source: Skertchly & Skertchly, 2000)

Indigenous communities across northern Australia perceive that bushfire is an important environmental hazard (Monaghan & Taylor, 2003, p. 179). Bushfires are often considered

more serious than the cyclones and floods during the wet season, due to their frequency and unpredictability. Bushfires can spread quickly and engulf unsuspecting and unprepared outstations, camps and travellers.

An initiative to control hazard in the communities of Pormporaaw and Kowanyama involves each meeting to formalise the fire regime ('smoke the land') at the end of each wet season. The goal for each community, town and outstation is to fence off the perimeter and create a buffer zone of bare ground around a portable and/or *in situ* water supply. Fuel is stored in elevated storage (Monaghan & Taylor, 2003, p. 181). When new bush camps are initially established, the ground is cleared with fire before the temporary structures are erected. NAFI (Figures 3, 4 and 5) satellite imagery reveals the intensive fire regime occurring in traditional lands. Frequently, fire scars can be seen to burn into neighbouring rangelands, resulting in loss of pasture for cattle. The climate change created disasters as described by Barros, (IPCC, 2014, p. 1) and its effects on traditional societies is suggested to affect the indigenous and the disadvantaged of the Mitchell River catchment. This is caused by the loss of, or change in the use of land, traditional food sources etc. A response from all of Government agencies may require a socio-legal response in order to assist those to sustainably adapt to the changed environment. Barcelos, Hicks and Marlow (2010) state:

> *It is certain that the survival ability of many of the world's indigenous and most disadvantaged peoples is at stake. And yet, the law is inadequately prepared to deal with these human impacts of climate change* (p. 193).

Another example, illustrative of this socio/legal concept, is proposed by the Mary Robinson Foundation (2011):

> *The international rights framework provides a reservoir for the supply of legal imperatives with which to frame morally appropriate responses to climate change, rooted in equality and justice* (p. 1).

The alarm call for action on sea level rise was made by an indigenous elder Inherkowinginambana from Kowanyama. Castillo (2009, p. 1) submitted this call as a demand for indigenous climate justice in the Mitchell River catchment.

In summary of this section each of the various characteristics of vulnerability applicable to the population of the Mitchell catchment is described. The aim was to consider vulnerability primarily to climate change induced hazards. The path by which these individuals and communities experience a hazard and their reaction and capacity to respond to the threat is described. The underlying exposure to vulnerability is presented within the social structures the residents are living. Importantly, the cultural dissonance between modern (western) and indigenous philosophy on understanding and existing in and with the environment is discussed. In addition, consideration of the process of recognition of, and response to a hazard by persons or communities within their particular philosophy is discussed. The advance of communities when coping within these factors determines their path into the next category and is presented in the following section.

2.6 Resilience and Adaptation

The IPCC Working Group II (2014, p. 37), in an introduction on the development of resilient methods, advocates, for example, improvements to health systems to respond to the impact of disasters from climate extremes. The National Strategy for Disaster Resilience (NSDR, 2011) identified the lack of an internationally recognised description or definition

of disaster resilience. The question, ‘what does a resilient community look like?’ is therefore, they suggest, problematic to define or describe within the context (pp. 5–6). However, they do define and describe a disaster resilient community as one where:

1. People understand there are risks which may affect them locally and nationally and are adaptable to react and respond to disaster.
2. People are prepared for/protected from impacts of possible disasters to minimise human, cultural and property loss through organisational provisions and resources to aid recovery.
3. People collaborate and co-operate on a local, community and regional level to deal with disasters using resilient personal and community networks.
4. Preparedness planning does and will develop community resilience over time.
5. Adaptive resilience-based outcomes are developed by communities, governments and other organisations considering and developing core services, products and policies.
6. There is a strong volunteer base for the emergency management sector.
7. Commerce and service providers implement strategic disaster planning and insurance.
8. Land use, planning and building controls reduce hazard exposure or risk in a disaster.
9. Post-disaster, relief and recovery enablers are rapidly positioned and operational, with an awareness of services available, with priority given to the most vulnerable COAG (NSDR 2011).

Paton (2005, p. 5) defined resilience as being formed from two discrete components where the scenario is drawn of a community’s ability to rebound from an adverse event, utilising its internal resources to recover. The critical components thus identified are (1) resources and (2) preparation. King (2007, p. 44) states that: ‘*Resilience is the key to learning from disasters*’.

Disaster studies identify the range of factors and failings contributing to the effects of a disaster, with a goal of providing physical and social structures and procedures to reduce vulnerability. From this diversity, McAslan (2011, p, 1) contributes his interpretation:

> *Resilience is ability of something or someone to cope in the face of adversity, to recover and return to normality after confronting an abnormal, alarming and often unexpected threat.*

This is seen to encompass concepts such as: '*awareness, detection, communication, reaction (if possible, avoidance) and recovery'*. These characteristics are instinctive and representative in the basic human struggle for survival. The definition is flexible and able to be adaptive to the ever-changing and hazardous environment. The author cites Walker et.al, (2005, p. 1) who define resilience concisely as: *'the ability of a system to absorb disturbance and still retain basic function and structure'.* Geleta (2011, p. 1) submits that the definition of resilient communities held by the International Federation of the Red Cross is those which are: *'able to adapt to, withstand and recover from external and internal shocks that make them vulnerable'*. Shaw (2012, p. 309) identifies three kinds resilience. The one applicable to the catchment population is termed as '*bouncing forward*'. This could be the response to a climate changed induced crisis by adapting to a new reality of sustainability in the altered environment.

Personal and community health is considered by Haikerwal (2011, p. 2) to be critical to develop resilience in disaster management and recovery. Creation of resilience is a critical step into the development of adaptation. Nelson, Adger, and Brown (2007, p. 397) define adaptation as a process of deliberate change in anticipation of, or reaction to, external stimuli and stress. Adaptive capacity, they suggest, is: *'the preconditions necessary to enable adaptation, including social and physical elements and ability to mobilize these*

elements' (p. 379). They consider that popular research processes are focused on an '*actor-centric'* view, seen to manifest for example when emergency services respond as an agency of '*social actors'* to specific environmental stimuli. Their primary concern is reducing the effects of the potential hazard. They suggest that research studies of adaptation and resilience are derived from separate disciplines and traditions of thought. The result is a crossover or communication deficit between the disciplines. Therefore, the authors seek to focus on an analysis of the relationship existing between the two and seek to identify the complementary characteristics. As a result, they promote a dynamic, resilience approach to hazard management. This is concerned with frameworks that result in the development of resilient social-ecological systems based on the core concept of change being a fundamental characteristic of any system. Implied within this concept is the transitory notion of the level system ***adaptedness***' (p. 400), which also changes with the context. They draw a contrast between adaptation literature (p. 412, and resilience literature (p. 410), (focusing on development of resilience to respond to uncertainties and sustain required flexible change). Therefore, the authors determine that the resilience model for adaptive actions is a suitable structure within which to study and analyse adaptive processes and identify the best policy response. In adaptation processes, they discriminate between '***incremental adjustments*'** used by agencies to manage systems to adapt and dynamic and deliberate/unintentional '***transformative actions***' (p. 404) that develop resilience when current social economic or environmental conditions become unsustainable. However, they suggest that sources for resilience leading to adaptive progress are common to each other.

The Insurance Council of Australia [ICA] (2011) in its description of a resilient community, closely follows ideals prepared by the NSDR (2009, pp. 2–15) for the Council of Australian Government [COAG] (2011, pp. 8–9) in that:

1. The population is aware of hazards peculiar to their community and have the knowledge, skills and abilities to respond to disaster and to consider the most vulnerable and exposed citizens.

2. Protective measures are implemented by the population to anticipate disasters and prepare and protect both themselves and their property.

3. The population has a high level of hazard knowledge and awareness and is able to implement and respond to disaster.

4. The community, in anticipation of disaster, responds by protecting its economic, physical and cultural assets both from the hazard and the recovery period following. The insurance industry is crucial at this point.

5. There is co-operation within the community and its leadership to utilise its resources and networks to prepare and provide support in times of disaster.

6. Individuals partner with emergency services, local government and non-government organisations prior to, during and post-disaster.

7. There are resilience-based disaster management plans designed to build community resilience over time.

8. The planning of policies, services and products by governments, organisations and communities have a disaster-adaptive, resilience-creating focus.

9. The volunteer sector of emergency management is robust.

10. Industry, commerce and service providers network to arrange security and emergency actions.

11. Land use and built environment planning agencies incorporate suitable design to provide inherent protection to the population and property from hazards.

12. Post-disaster restoration and rehabilitation is realised in a short time-frame with the population aware of support services and facilities available to them (pp. 2–33).

Following the live beef export ban the catchment population would seem to have adopted a notion promoted by Bonanno (2004, p. 20) in which, resilience is developed for many people from a wide range of stimuli and is a positive outcome of trauma or disaster. **Recovery**, he describes as the continuing journey from the time of the trauma. A part of the journey is post-traumatic stress which may last for many months. Here the victim only occasionally experiences periods of relative normalcy. The journey of gradually returning to pre-trauma function may take two years or more. Resilience, in contrast, is a relatively stable psychological and physiological state with only transient episodes of subclinical depression. Haikerwal (2011, p. 3) also recognises the demand for psychological support as part of the recovery process and is striving to provide support for the carers in the field. The catchment community, upon attaining resilience, has adapted and progressed to the status of a prepared community.

2.7 Preparedness

Effective resilience and adaptation during a disaster is enhanced by preparation to an anticipated event (Paton, 2005, p. 7). Preparedness is determined by Paton (2005, p. 5) to be: *'the process by which resource availability is encouraged'*. This is the coordination of formal and informal organisations and their competencies necessary for communities to adapt to a disaster or threat. Resources are the range of human and physical assets necessary to expedite the coping mechanisms required to respond to a disaster. The adaptive capacity so generated is then able to be directed across the impact, response and recovery phase of an event. Critical to the process is the dynamics that interact within the community as it progresses through the recovery phase to meet emerging issues. Barriers to emergency preparedness that prevent people from preparing themselves may lie in the perception and attitude various groups must risk. Renn and Rohrmann (2000) conducted a cross-cultural

study on public attitudes to risk assessment across ten countries. Because of their work, they suggest a range of cognitive processes utilised for evaluations forming risk judgements that are dependent on social, cultural and national heritage. They cite the studies of Goudie (1999) who, in his research within multicultural groups, determined that many groups of people residing in hazard zones require information of the type that creates the reality of the severity of the situation in their mind. He has identified socially marginalised and disenfranchised groups to be at risk and to ensure their safety, they need special attention in a disaster event. Renn and Rohrmann (2000) determined that, in developed countries, westerners perceive risk in terms of a gamble. Renn and Rohrmann (2000, p. 39) recommend that, to convince such populations, the strategy should be to *'make the threat real'* by media projecting the expected number of fatalities and possible damage expected.

Following withdrawal of immediate relief, the recovery period will endure over time and may not have the availability of, or access to, necessary support. King (2007) concludes with the following summary regarding households and communities:

> • *There is a lack of transfer of knowledge and awareness between different types of hazards;*
>
> • *Information technology gives emphasis to places and events that are better connected;*
>
> • *Distant events learnt about are the biggest, and in a sense, the easiest to ignore because they are extreme;*
>
> • *Most information is received on the most local events that, most of the time, are not extreme disasters - thus communities remain unprepared for a truly catastrophic event* (p. 47).

The Review of Recent Australian Disaster Inquiries Goode, et.al, (Section 3.2.1. p. 16) has commented on the repeated problems resulting from less than adequate state emergency arrangements which, in turn, have compromised the effectiveness of disaster response. Paton et al. (2009) determined that both community members and emergency services providers were able to influence disaster preparedness of the individual, independent of provided information. Advanced planning and preparation for a disaster is critical. Hazard preparedness planning needs to incorporate the social context in which the population lives. Effective risk management requires that each of the roles of emergency management agencies and individuals become integrated. For this ideal scenario to be realised, people and communities need to be empowered and contributions integrated into the action plan relevant to their area. Such a concept of social amplification of risk is based on the fact that events pertaining to hazards interact with psychological, social, institutional and cultural processes in ways that heighten or attenuate individual and social perceptions of risk and shape risk behaviour (Renn, 1992, p. 139). People sometimes lack information about hazards. However, their basic concept of risk is much richer than that of experts and reflects legitimate concerns that are typically omitted from expert risk assessments (Renn, 1992, p. 142).

2.7.1 Environmental Preparedness

Environmental preparedness of the Mitchell River community is a goal of this study because a small population spread out over a large area would severely be at risk facing a disaster. Most of the catchment is isolated during the wet season due to high river levels across causeways and the unsealed roads are impassable. Access and resupply is only possible by air. Kowanyama is an island in the vast flooded delta and subject to frequent cyclones. Relevant to the catchment, particularly after the bushfire disaster (2012, Figure 4)

in the western catchment is the study by Paton et al. (2010) who is concerned with the sustainability of societies when they are exposed to, and coexist with, natural hazards due to their geographic location (e.g. earthquakes, volcanic eruptions). They examined the interpretative processes people undergo when recognising a hazard, which is also influenced by the relationship they formed with a hazard and the trust developed through the nature and source of information provided. Their goal therefore was to identify and quantify factors that, in combination, interact to incorporate risk management activities within community development strategies.

The increasing global phenomenon of disaster risk was investigated and commented on in the Australian context by Keogh et al. (2011). Citing the 2008 Garnaut Review, they suggest that, in terms of developed countries, Australia is more vulnerable to climate change as the predicted increase in temperatures, heatwaves and frequency of climate extremes may result in an increase in bushfire prevalence and more severe droughts and floods. They reviewed those factors that affect community recovery and are listed (p. 700) to be: economic, physical, community, environmental, financial, psychological and emotional.

2.8 Australian Disaster Mitigation

The implementation of a range of planning, building, land use and development codes can help emergency response organisations mitigate risk. These national, regional and local groups are charged with assisting risk reduction and recovery management following a disaster. Effective organisations depend on the nature of communities who value quality relationships and active communication. These play a vital role in reducing vulnerability and increasing resilience and adaptability prior to and following a disaster. For example, Henderson (2011) determines the preparation required for cyclone and wind damage to

Australian buildings. The wind map (Figure 9) notates wind strengths expected during storms in Australia, with the Mitchell River catchment classified in wind load categories A (160 km/hr), B (205 km/hr), and C (250 km/hr). These categories are tested to determine the loading on structures as wind speed increases. Cyclone Ita (10 April 2014, Category 4, > 225 km/hr) successfully tested the emergency and structural preparation in the eastern parts of the catchment and lessening to category 1. The Severe Tropical Recovery Plan (2014) recognised significant damage to sugar cane, banana and horticultural crops within the catchment. Electrical distribution and transport infrastructure suffered wind and flood damage. All repairs were completed in 2015. The knowledge gained has been directed into the Natural Disaster Relief and Recovery Arrangements (NDRRA) to improve future disaster responses (p. 18).

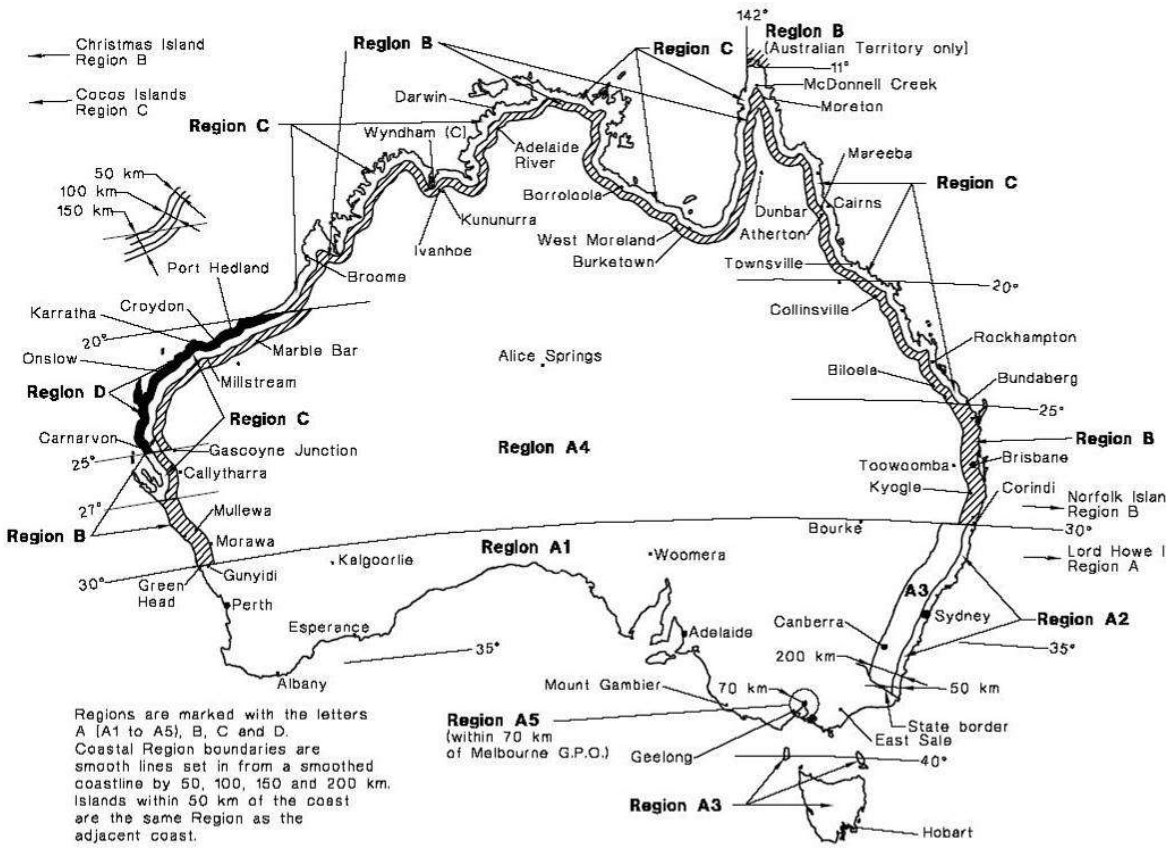


Figure 9 Wind load standard

(Source: Henderson, 2011, p. 13, AS1170.2, 2002).

2.9 Conclusions and Research Question

The aim of this chapter was to review the available literature which may inform the catchment population of the recognised hazards as they experience climate change impacts. Unfortunately, much of the information was sourced from the grey literature that commercial and governmental agencies distribute. Independent sources and publications are not available. As climate change events increase in impact across the catchment, the strategies that government agencies, commercial enterprises, graziers and private individuals have, and do, employ to mitigate the effects of climate change need to be studied. These strategies combine to create the necessary adaptations which are considered and evaluated within the philosophy of the Garnaut Climate Change review (2008, p. 364), (Thesis Ch. 3.8, p. 81) introducing the four relative advantages of business and communities collaborating to adapt to climate change and considering limited government abilities.

In due course, the economy, environment and society of the catchment will develop resilience, hopefully through its own efforts. This material helps to pose the research question of this thesis is whether residents of the catchment decide to initiate mitigation strategies on their own initiative, or delay action until external governmental and commercial agencies impose compliance upon them. The need for a finding on this preparedness thesis is formed on the experience of the disaster management researchers who have contributed in this chapter. The environment of the catchment is expected to depend on a well-connected resilient and adaptable community with high levels of social capital. This literature review will, hopefully contribute to the resolution of the question.

Chapter 3

Mitchell River Catchment

3.1 Mitchell River Catchment Profile

The reason for the Mitchell River catchment being selected for this study is that this land form combines all the components of the hydrological cycle within a defined area suitable for a quantifiable study. Wagener et al. (2004), Sivapalan (2005, p. 2), and TRaCK (2013) suggests that a catchment is the most fundamental land form for the cycle of water, sedimentation, geochemical and biological matter. The Mitchell catchment is here promoted as an ideal site for study. Catchment hydrology theory promoted by Wilby et al. (2006) incorporates global change science with eco hydrology and complex systems science. They suggest that catchment research science is a source of extensive study and literature across catchments. Unfortunately, a paucity of data exists for the Mitchell River catchment area, so this project may prove useful to add to the Mitchell catchment database. The Mitchell River catchment area (Figure 1) covers some 72,000 km² of Far North Queensland (FNQ). It drains from the Wet Tropics World Heritage Area on the western slopes of the Great Dividing Range westward into the Gulf of Carpentaria along 15,425 km of the Mitchell, Walsh, Alice, Palmer and Lynd Rivers. On average 11.3Gl of fresh water is discharged from the catchment area into the Gulf of Carpentaria each year, and, as such, is one of the largest river systems in the state in terms of average annual discharge.

Monsoonal type rainfall across the region varies from an average of 1,340 mm in the upper Mitchell River and tributary streams to 825 mm in the central plains of the area, rising again to about 1,255 mm on the Gulf of Carpentaria coast. The ‘wet season’ supplies 80% of precipitation and runs for four months from December to the end of March. Evaporation rates (the rate at which a dam will deplete) are high at about 2,225 mm per annum in the

region's centre. This necessitates high crop water needs and significant storage losses for water harvesting projects. Stream flows in the region reflect the rainfall in variability and seasonality. The upper Mitchell River and its tributary streams flow year-round, primarily because of the high rainfall in the upper catchment and a small amount of sub-artesian water discharged from surrounding aquifers and flows from cloud forests. The summer flooding and absence of flow during drought and dry seasons is characteristic of Gulf Rivers. Wet season floodwaters can breach the Mitchell River catchment boundaries and spill into the adjacent Staaten River. The Northern Australia Land and Water Science Review (NALWSR) report that during the 'big wet' the catchments of the Mitchell and those draining into the Gulf plain area may be simultaneously inundated (2009).

The Mitchell River Catchment Resource Plan (2009) reported that this catchment is a highly bio diverse region that contains four bioregions and their unique vegetation communities (Figure 10). These regions include the World Heritage-listed Wet Tropics, Einasleigh Uplands, Gulf Plains and Cape York. The vegetation communities supported include Melaleuca-dominated woodlands, tropical rainforest, Mitchell grassland, mangroves, mudflats and wetlands of national significance. The report found that the lack of baseline data makes it difficult to estimate exactly how many rare and endangered species exist in the catchment. Studies to 2009 indicate that 18 species of animals are classified as rare, endangered or threatened. These include the Golden Shouldered Parrot, Gouldian Finch and the Northern Bettong. A scarcity of data exists for freshwater aquatic species except for the study completed by MRWMG, (2009) who reported on the endangered northern sawfish (*Pristis microdon)* in the upper reaches of the catchment. This report also points to the risks posed by unsustainable agricultural production on the health of these ecosystems.

Further increase in erosion and sediment accumulation in the Mitchell's river systems could result in impacts on the estuarine and marine fisheries. Permanent waterholes in the catchment that create refuges during the dry season could be at risk of being filled in by sediment created by agricultural development. Research that has been undertaken by 'TRaCK' researchers found that the Mitchell River catchment is already at risk of sediment accumulation from intensive land uses (Mitchell River Catchment Regional Plan [MRCRP], 2009).

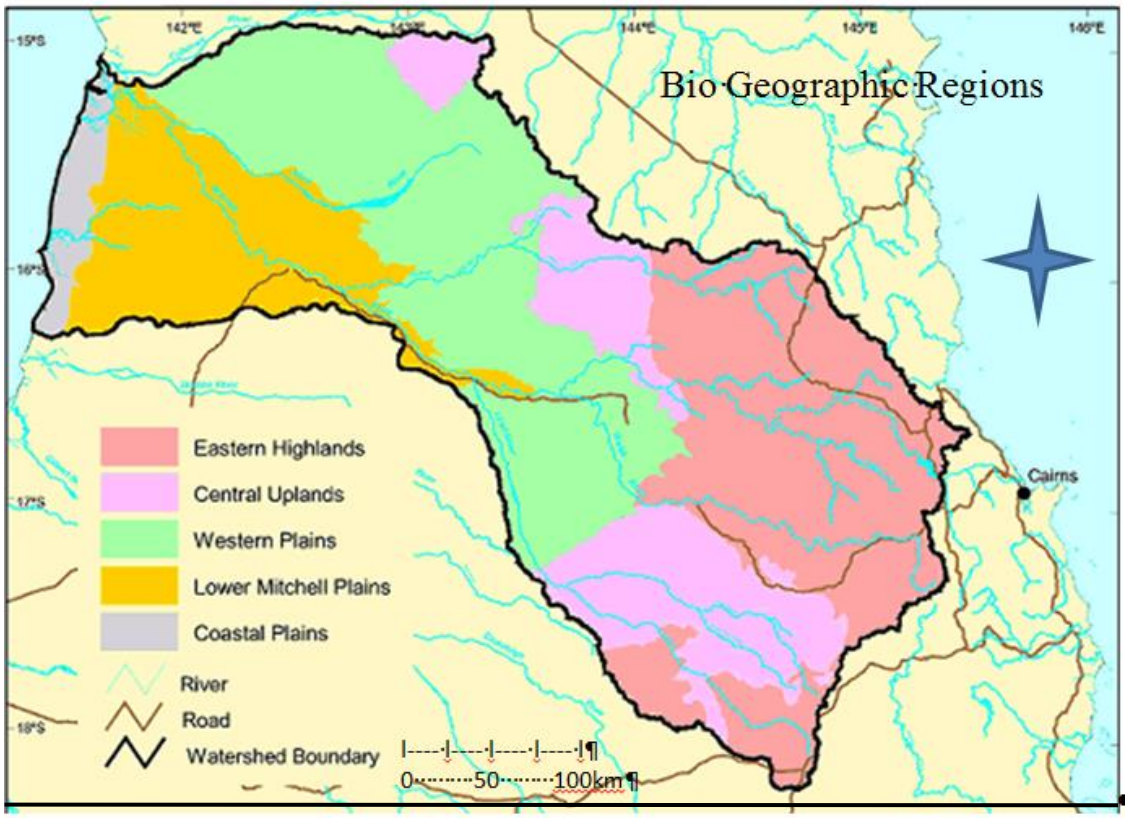


Figure 10 Biogeographic regions of the Mitchell River catchment

(Source: MRWMG, 2013)

Tropical Rivers and Coastal Knowledge is a consortium founded in 2007 and consists of 18 organisations including universities, CSIRO, state and federal agencies. These interact to provide the science and knowledge that governments', communities and industry need for the sustainable use and management of Australia's tropical rivers and estuaries. Significant work has, and is, being completed within the catchment (MRWMG, 2010, p. 1).

Currently there are 14 ‘TRaCK’ research projects actively underway in the Mitchell River catchment. The projects cover topics as diverse as erosion and sediment transport in the Mitchell River, economic interactions between indigenous and non-indigenous economies, flood water flow and its effect on the productivity of estuarine seafood stocks. One finding is that the level of the seasonal flood peak directly affects the quantity and size of fish available to harvest both in the river and the Gulf. (TRaCK, 2010, p. 14).

McJannet et al., (2009) in the environmental description of the Mitchell-Gilbert River Fan Aggregation in the delta consider it a significant example of a diverse and rich array of alluvial plain wetlands and deep-water habitats. It is characterised by extensive areas of semi-permanent and permanent wetlands providing a habitat for many species of waterbirds. The area is of great importance to the indigenous residents centred on the Kowanyama community (p. 91).

3.2 Population and Community

The indigenous population at Kowanyama is the largest community (Figure 14) in the catchment. The Australian Bureau of Statistics (ABS) reported that, in 2011, the population was 1,058, of whom 87.5% are reported to be indigenous with a per capita weekly income of $293 and with four persons per household (ABS, 2011, pp. 1–2). The importance of cultural heritage and caring for country is part of everyday life for the indigenous people of the Mitchell River catchment. Documenting places of significance has only recently been undertaken with an enormous amount of work still to be done. Many of these sites are located along watercourses, wetlands and waterholes. Protecting these places is paramount if development in the area is to be considered, with significant consultation with the traditional owners needed (MRCRP, 2009).

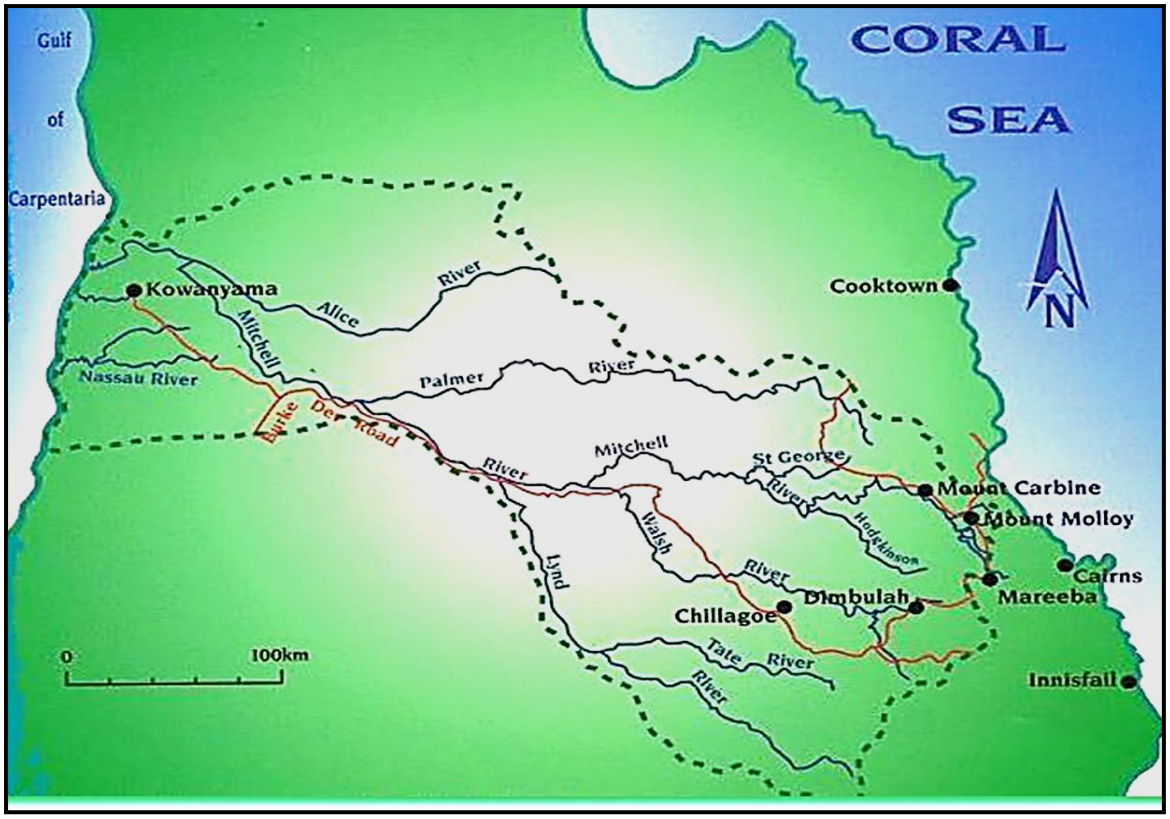


Figure 11 Communities of the Mitchell River catchment

(Source: Kowanyama Aboriginal Shire Council Corporate Plan, 2011– 2016, p. 3).

The tribal groups are comprised of the *Yir Yorant (Kokomnjen), Kokoberra, Kunjen* and *Kokoberrin* groups, amongst others. *Yir-Yorant* is the language in use by much of the community and, in this language, Kowanyama means '*place of many waters*'. The community is located on the Magnificent River, a tributary of the Mitchell River, 20km inland from the sea (Cape York Sustainable Futures 2009, Department of Aboriginal and Torres Strait Islander and Multicultural Affairs, 2014, p. 5). The Kowanyama community is the recipient of an historic native title determination, their first. Native title rights are recognised over about 2,731km² of land and waters. This is part of a much larger claim over a total area of 19,800km², which includes Kowanyama community and a coastal strip approximately 160 km long from Coleman River to Staaten River. Kowanyama community tribes the Yir Yorant (Kokomnjen), Kokoberra, Kunjen and Kokoberrin people were handed

back ownership of the 37,000ha Mitchell/Alice Rivers National Park in 2009. This is the first existing national park in Australia to be returned to traditional owners. Situated 30km north east of Kowanyama, it will be renamed the Errk Oykangand National Park (MRWMG, 2009).

Monaghan (2006) has researched the practical application of land tenure and practice within the 1987 Deed of Grant in Trust (DOGIT) land area. He explored the complicated interaction of the habitual, established practice and custom of land tenure and geography. This topic is explored considering the community interaction between implicit (implied or traditional, physical and social) space and explicit (unequivocal or temporary, physical and social) space.

Sharp (1998, pp. 10–14), in a not dissimilar way, explored the spatial use of coastal sea space by North Australian indigenous peoples. She contrasts colonial and contemporary conceptions of coastal marine space as an 'open access' area for all Australians. Indigenous peoples' concept of marine space is one of an inherited marine, and common property. Her concept for a paradigm, '*reimagining*' is introduced for non-indigenous people to be able to comprehend indigenous peoples' concept of marine space.

Strang (1997) conducted ethnography of the culture of indigenous and non-indigenous population of the lower Mitchell River centred on Kowanyama, within a geographical and historical context. The cultural interface between indigenous and non-indigenous cultures is explored through the cultural values each group assign to the human, economic and physical geography, its use, symbolism and hierarchy. She found that non-indigenous peoples are isolated from the land due to technology, mobility and social status with two different world

views emerging. This concept is of relevance to this research project. The contrast is that indigenous inhabitants are in relationship with their land and share a social and spatial affinity, founded on equality and uniformity. She also recognised that the indigenous landscape is one that has been transformed by non-indigenous settlement and importantly concludes:

> *It seems that today, while Western culture is faltering and beginning to question many of the values it has prioritised, Aboriginal culture is quietly re-establishing a solid and sustaining environmental relationship* (p. 290).

A new dimension affecting the cultural characteristics of the indigenous community in Kowanyama is sea level rise. Cultural characteristics of the region are affected by climate change. Castillo (2009, pp. 1–4) detailed the experiences of Kowanyama elders and rangers who are searching the coastline for aboriginal artefacts and tools that are collected and stored for protection from the rising sea level. The research determined that:

> *…without access to freshwater and the biodiversity that depends on freshwater ecosystems, Aboriginal people of Kowanyama may be forced to adapt to a very changed coastal landscape* (p. 2).

She theorises importantly that:

> *...these biophysical changes are encroaching on spiritual and conceptual boundaries that are so integral to Aboriginal identity* (p. 1).

3.3 Catchment Statistics

Unfortunately, the statistical areas boundaries do not align with the catchment boundaries, so interpolation of available data was applied to provide a representative map (Figure 12), of the population. For example, the Arriga statistical area mostly falls within

the catchment, but includes the Lotus Glen Correctional Facility (large male population), which is located just outside the catchment boundary. The Tablelands (Level 1) Statistical Area covers a large portion of the catchment centred on Chillagoe and is named after the Einasleigh Uplands region known regionally as the Tablelands. The ABS data for the local government areas provide data representing the developmental stages of life (hatched area), in a 5-yr. bracket for the 0–4 yr. cohort (preschool) while the 5–14 yr. indicate the primary school cohort. The 15–19 yr. set cover secondary-tertiary aged cohort and 20–24 yr. set undertaking post-secondary training and education. The remainder are set in a 10-yr. cohort (Figures 13, 14, and 28). The data from selected divisions and suburbs (Figure 12) were collated to form Figure 13 to give a representative population profile.

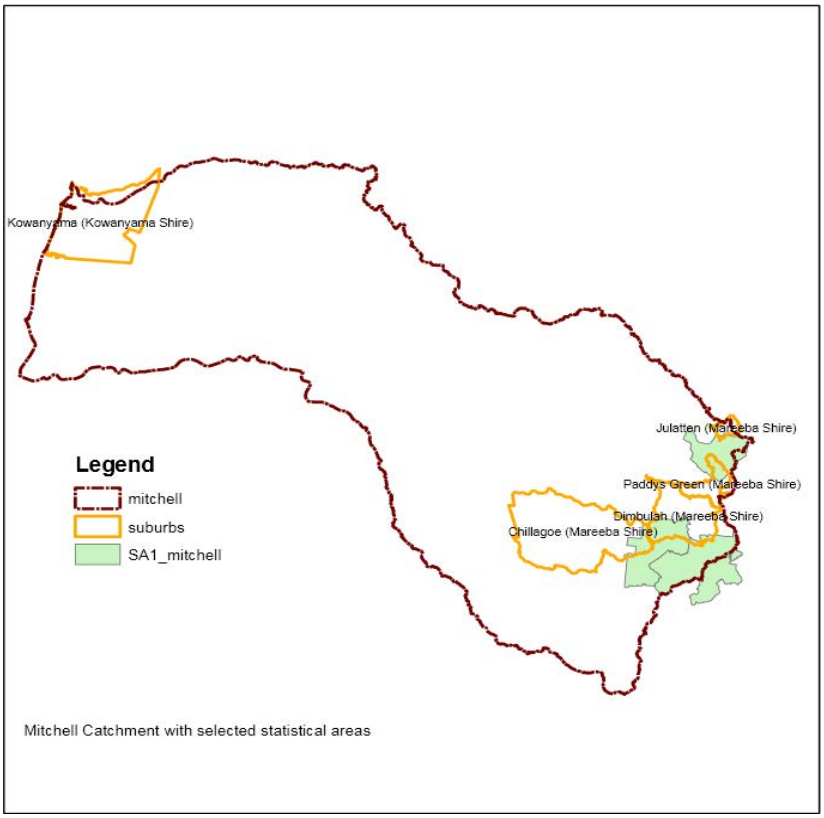


Figure 12 Mitchell River catchment with selected statistical areas

(Source: ABS, 2013. Map drafted by A. Edwards)

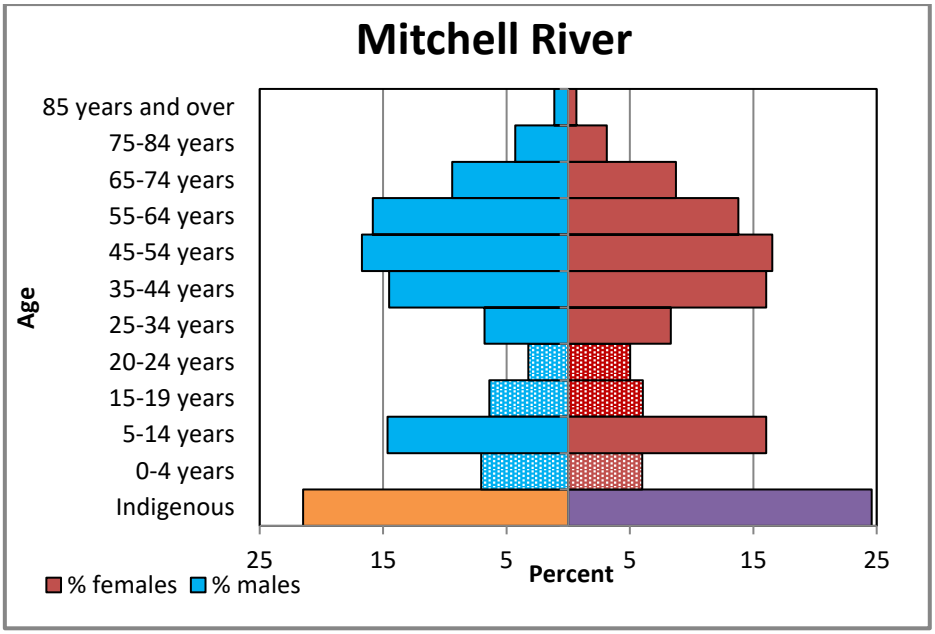


Figure 13 Mitchell River population profile (8,470km2)

(Source: ABS, 2011 census)

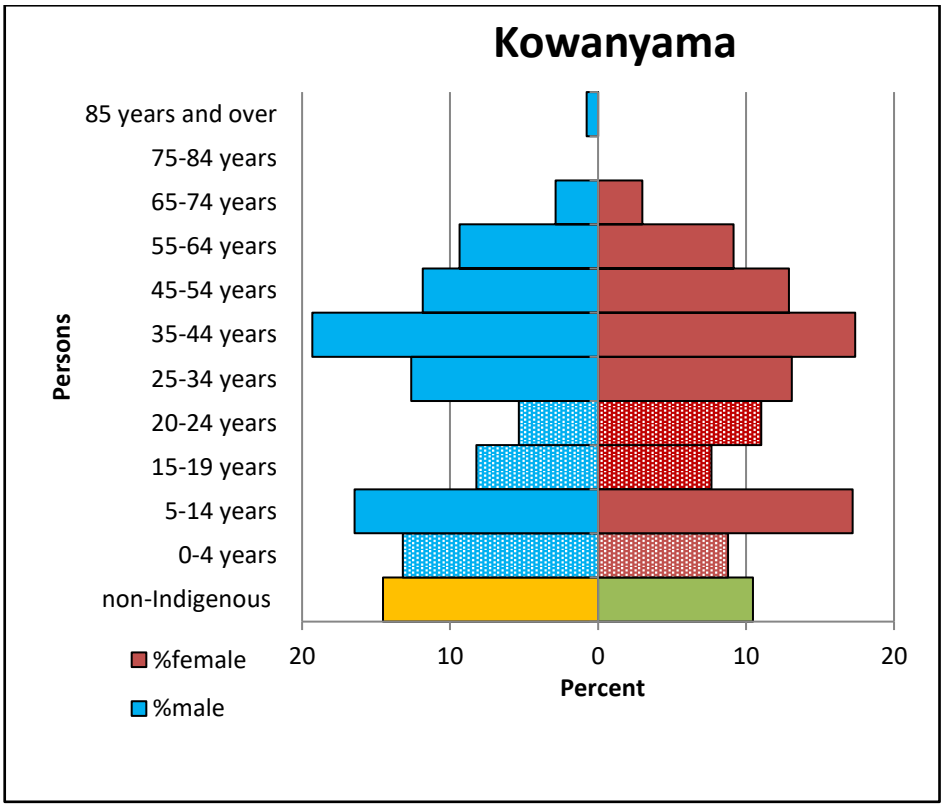


Figure 14 Kowanyama (2,543 km^2) population profile

(Source: ABS, 2013)

The age profile (Figure 13) generated from the 5,252 persons counted in the 2011 census

(Figure 12) displays a bias toward middle to older age individuals over the whole catchment. Kowanyama (Figure 14) is characteristic of remote indigenous communities. The decrease in persons in the > 64yr age group reveals the shorter life expectancy of indigenous persons (Larson, 2006, p. 1). However, a feature of the outlying value in the > 85 yr. category is 100 yr. old Mrs May Smiler from Kowanyama, the oldest recorded Queensland Aboriginal person (Queensland Government, Aboriginal and Torres Strait Islander and Multicultural Affairs, June, 2014).

Across the statistical areas of the catchment, the 15 to 34 yr. age brackets display a marked decrease in youth and young adults, which is a similar pattern to that of the Australian remote and rural demography in general, as many have moved to cities for education and employment opportunities (Larson, 2006). This phenomenon raises concerns because ideally, young adults provide the core of the workforce and are fit to respond to disasters. Another concern illustrated by Figure 13 is those in <15 yr. and >65 yr. cohorts, fall within categories that Buckle (1998, p. 23) and Cutter et al. (2003, p. 251) classify as vulnerable groups in a disaster.

Table 2 Comparison of Tablelands and Kowanyama statistical division in Australia

Statistical Area	Median Total Household Income ($/weekly)	Average Household Size	Median Age of Persons
Tablelands	$795	2.5	42
Kowanyama	$1071	4.0	28
Australia	$1234	2.6	37

(Source: Australian Bureau of Statistics, 2011 Census)

Income across the catchment is compared in table 2 with the Australian average and

displays a marked disparity in household income compared to the Australian median, particularly when faced with the much higher cost of living in this remote area. For example, the researcher found the cost of groceries and fuel in Kowanyama at least twice that of Cairns. The IPCC (2014, p. 9) considers that households of low socio-economic status and particularly those who are indigenous, are more vulnerable to climate change hazards and may suffer from economic and health effects (p. 9). If this consideration is extended to the indigenous community at Kowanyama and the residents of the Tablelands, it is suggested that they are much more vulnerable to hazards than the average Australian.

3.4 NGRMG Community Survey

To gain an insight into the more intimate attitudes and beliefs of residents of the Gulf Region, the Northern Gulf Resource Management Group (NGRMG) conducted a limited, phone book listed, Gulf community telephone survey in November 2010. This reported on a range of issues identified as significant to the catchment residents. The goal was to ascertain community reactions as to where regional funding should best be spent and to determine awareness and reactions to practices and policies of NGRMG. Because no phone book was available for Kowanyama many indigenous persons of the catchment were not surveyed. The survey separated results from the 149 Mitchell catchment residents from the wider study. The catchment residents considered that the ten most popular projects for their region were:

1. Continuation of the Ghost Nets (Gunn, et.al, 2010) project (44% support).
2. Continue to implement the Gilbert River rehabilitation project to aerially ignite rubber vine and other weeds to control infestations (46% support).
3. Assistance to farmers in the Mareeba/Dimbulah irrigation area to adopt best land management practice (22% support).
4. Assist grazing enterprises to support sustainable management practices (24% support).

5. Continue the grazing land management programme (24% support).

6. Facilitate local communities in recording local history and stories (27% support).

7. Assist farmers to improve productivity and reduce fertilizer and water use (18% support).

8. Continue the terrestrial biodiversity survey programme to gain information and act on threatened native species and communities (16% support).

9. Create an online biodiversity field guide to identify plants and animals for public use (18% support).

10. Develop business models for community owned conservation areas and facilitate local employment and skills development (13% support) (NGRMG, 2010, p. 9).

During the NGRMG catchment survey project the respondents' ranked the topic of climate change as low in importance. However, the relevance of this survey to this thesis is that all the ten issues rated as significant in the telephone survey, fit with the range of adaptation and mitigation strategies also recommended in the findings of this thesis (Chapter 5). All these projects, when implemented, provide valuable tools to aid in the mitigation of the proposed effects of climate change. Land management, pest weed control, reduced stocking-rates, education and environmental awareness all conform to be desirable strategies for climate change adaptation.

Fifteen new projects were proposed by the NGRMG. For respondents in the Mitchell River catchment area, the top ten of fifteen in popularity are selected due to their relevance to the catchment under the impacts of climate change. They are provided in their rank for the overall survey:

1. Working with local councils and land managers to manage weed and pest problems (51% support).

2. Develop primary schools educational curriculum based on local knowledge and experiences. (38% support).

3. Identify risk of heavy metal contaminants to the sea food in the Norman and Walsh Rivers (32% support).

4. Obtain improved prediction of weather events and plan for climate change (39% support).

5. Undertake wildlife surveys to identify the most significant areas to maintain wildlife to reduce potential extinctions due to climate change (18% support).

6. Reduce introduction of marine pests into the Gulf region by installing careening facilities (23% support).

7. Assist small miners to develop improved technologies to reduce their impacts and costs (15% support).

8. Research community-based management of local conservation areas and State National Parks and Reserves (12% support).

9. Fund Landcare and catchment groups to assist local level projects (14% support).

10. Develop management of habitat necessary for protected, endangered and threatened marine and coastal wildlife (16% support) (NGRMG, 2010, p. 11).

The respondents may seem to be ambivalent to impending climate events (NGRMG, 2010, Table 15, p. 8), but they have selected a range of strategies that have the effect to reduce vulnerability because these strategies could be sound climate change adaptation strategies.

3.5 Natural Resources of the Catchment

An important initiative in addressing climate change adaptation in the catchment is that of the creation and maintenance of a range of wildlife and biodiversity refugia. The conservation areas and national parks across the catchment provide some protection to flora and fauna. The Australian Wildlife Conservancy is a private trust with holdings in

biologically diverse and sensitive areas across Australia. One of its holdings is the Brooklyn Sanctuary (Figure 15) located near Mount Carbine, which has been established to allow protection of threatened native flora and fauna.

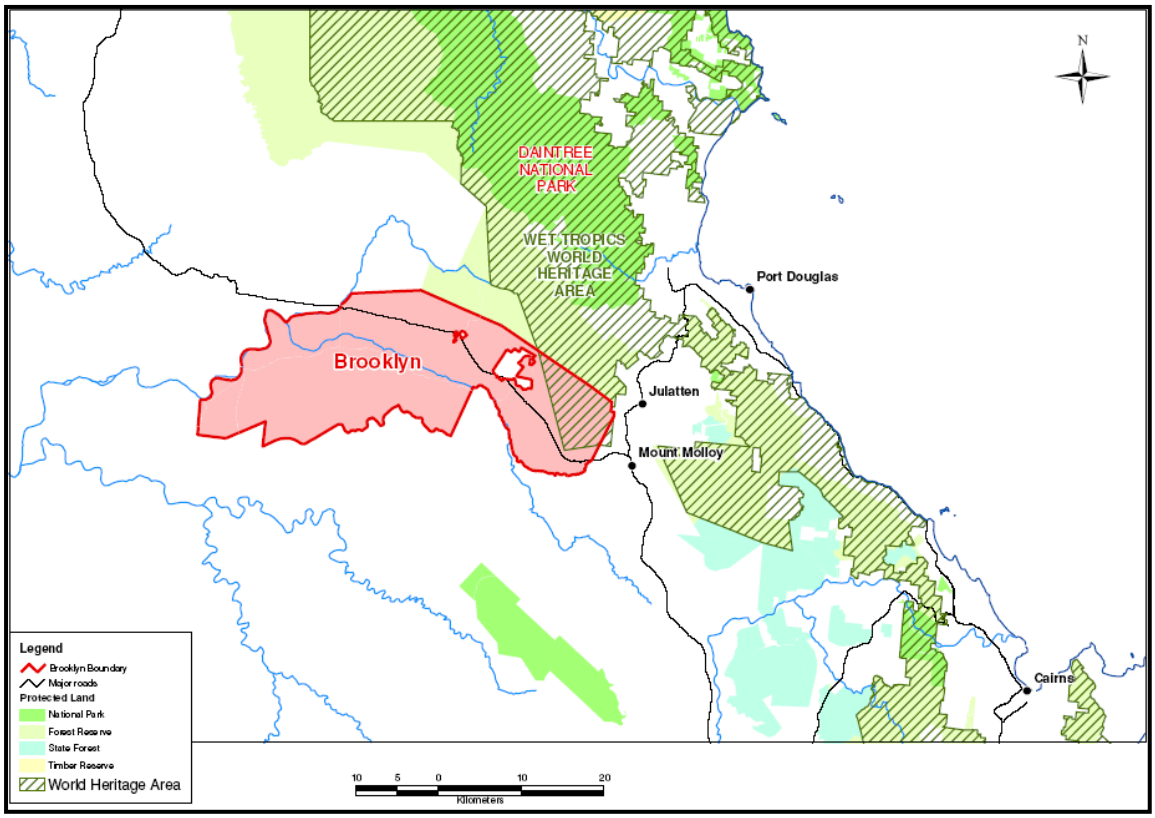


Figure 15 Brooklyn Sanctuary wildlife conservancy

(Source: http://www.australianwildlife.org)

Originally a cattle station, it has been destocked and is being rehabilitated into a sanctuary for over 200 species of birdlife. This area of immense biogeographic interest contains, for example, one of only two populations of the Bunya Pine (*Araucaria bidwillii*) in northern Queensland. The nearest location for these trees occurs in southern Queensland, over 2,000 km away. This rare and threatened ecosystem is suggested to be a remnant of a more extensive temperate cloud forest existing from some 40,000 years ago. This not-for-profit organisation utilises volunteer labour and gains funding from a sustainable eco-tourism business. Savanna and wetland research, education and conservation projects add to the activity of this conservancy. Of note is that the community survey conducted as part of this

research revealed the history of Brooklyn and the ongoing community interest in, and support for, the establishment and maintenance of this facility. Unlike the government national parks and conservation reserves system, Brooklyn is mostly free of external political and financial influence and actively contributes to, and has become a critical component of, the healthy eco-tourism economy contributing to the development of the region (Australian Wildlife Conservancy [AWC], 2014; MRWMG, 2013). The Julatten, Mount Carbine and Mareeba triangle has emerged as a major bird-watching area with over 190 species observed at Mount Carbine, 300 species recorded at Mount Molloy and over 200 sighted at Mareeba Wetland Reserve, including the elusive Buff-breasted Button Quail, Golden Shouldered Parrot, Gouldian Finch and Northern Bettong mammal (re-introduction of the endangered Gouldian Finch is underway within this and other reserves of this area). Within the catchment, other reserves with potential to mitigate the impacts to climate change by providing, for example, diversity, habitat, pest and weed control, fire management grazing pressure are:

1. Wet Tropics World Heritage Area located along the Great Dividing Range and containing the Mount Lewis National Park (Plate 1), north of Julatten.

2. Mitchell/Alice Rivers National Park, now renamed Errk Oykangand National Park (pronounced *'airk-oy-kun-gund'*). (National Parks Association of Queensland [NPAQ], 2012). More than the traditional concept of a national park, this is a '*living, cultural landscape rich in significance*' for the Uw Oykangand people (the language group of the *'people of the outside waterholes'*). Located on the western confluence of the Alice and Mitchell rivers, the park protects floodplains clad in bloodwood, box and paperbark woodlands, interspersed with creeks, waterholes and wetlands.

3. Chillagoe-Mungana Caves National Park, rich in natural and cultural heritage. It encompasses spectacular limestone caves, Aboriginal rock art, limestone outcrops and

Mungana, the historically significant mining site.

4. Further south is the Bulleringa National Park. This isolated park has no public access.

5. In the head waters of the Lynd River, the 40 Mile Scrub National Park is mostly located in the catchment. The features of this national park are ancient and recent volcanic flows, open grassy woodland and a *'near-threatened, isolated pocket of semi-evergreen vine-thicket'* (NPAQ, 2012).

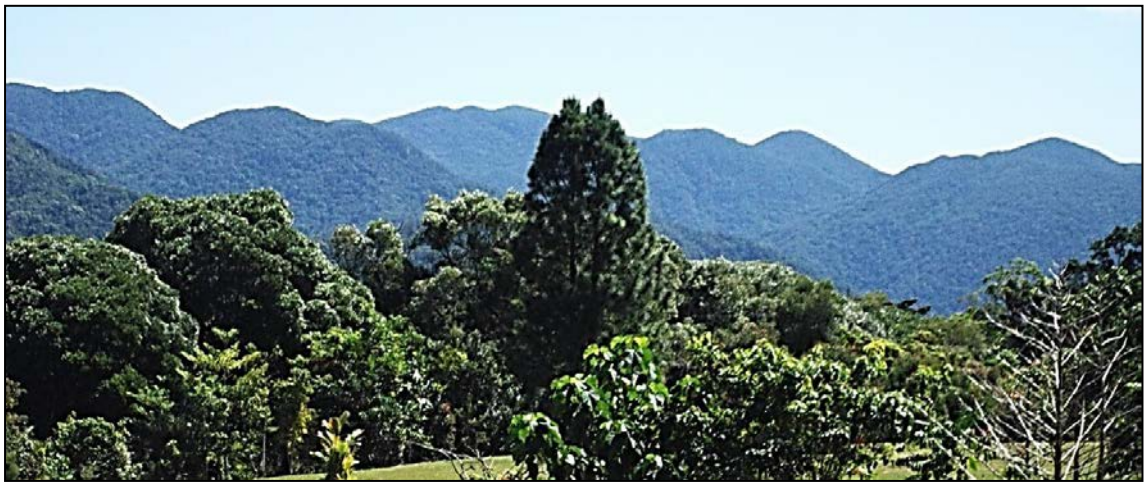


Plate 1 Mount Lewis National Park (Source: R. Beasley)

Visible across the catchment are the significant biomass of the subterranean termites and ants. Of the 263 termite species found in Australia, around 160 of these can be found in Northern Australia. Data on the species existing on the Mitchell Catchment is not evident. However, the researcher's field observation indicated an extreme abundance of the insects on the savanna. They may generate a biomass of hundreds of tonnes/km². This is far greater than the mass of cattle over a similar area (Smith et al., 1998; Andersen et al., 2012, p. 658). King et al. (1998) developed a model on the nearby Atherton Tablelands, where they suggest that ants act as important bio indicators for ecological change in the rainforests of the region. Supporting this model, Underwood and Fisher (2006, p. 166) conclude from their review of 60 published studies that ants are valuable bio indicators and are able: '*to*

assess long term ecosystem changes,' and therefore are suitable monitors of the effects of events such as climate change. Kutt and O'Reagain (2002) determined that termites constitute 10% of all animal biomass in the tropics, and up to 95% of soil insect biomass. They are the major determinants of soil structure and the biological processes that underpin soil health. Termites have been shown to have spectacular effects on soil hydraulic function, leading to increased rainfall use efficiency and pasture production. Many plant species rely on ants to disperse their seeds (myrmecochory).

These seeds have an ant attractant (elaiosome), which is a nutrient-rich attachment useful for attracting ants and enabling seed conveyance (Beattie, 1985). The benefits to the plant in the savanna is that they are protected from fire, dispersed and relocated to nutrient rich ant nests protected from predation by animals. Andersen et al. (2012, p. 658) suggest that fire regime in the savanna is the major determinant of ant population and species: '*frequent fire promotes ant diversity because it maintains an open habit that makes the dominant arid-adapted taxa feel at home'.* This study has not investigated the effects of climate change on these insects, but due to their sheer biomass, nutritional pressure and the interactions with bio-soil characteristics and structure, further study would need to include this characteristic for consideration and research.

Krockenberger et al. (2003, p. 5) suggests that the tropical forests of North Queensland are highly sensitive to climate change. Highland rainforests and their fauna are particularly vulnerable: e.g. an increase of only 1°C is predicted to decrease the area of some habitats by 50%. It is critically important that properties such as Brooklyn, which potentially includes areas that will act as greenhouse refugia for highland species, are protected and managed effectively for conservation (Pye & Gadek, 2004).

Noss (2002) suggests that policies that offer credits for carbon sequestration fail to consider the effects of biodiversity on forest management. The rationale is that, although forests have proven to be resilient to past climate change events, the remnant forests of today are more vulnerable. Past responses have been naturally *'phenotypic plasticity, evolution, or migration to suitable sites'*. Therefore, ideal policies and practices for forest biodiversity and ecological functions during climate change should be:
(1).representing forest types across environmental gradients in reserves; (2) protecting climatic refugia at multiple scales; (3) protecting primary forests; (4) avoiding fragmentation and providing connectivity, especially parallel to climatic gradients; (5) providing buffer zones for adjustment of reserve boundaries; (6) practicing low-intensity forestry and preventing conversion of natural forests to plantations; (7) maintaining natural fire regimes; (8) maintaining diverse gene pools; and (9) identifying and protecting functional groups and keystone species (Noss, 2012, p. 579).

The Department of Environment and Resource Management [DERM] (2010) have determined that: *'The conservation of the genotypes of the Mount Lewis population may be imperative for the future of a range of species, given predicted models of accelerated climate change over the coming decades'* (p. 1). Streams flowing into Mary Creek from cloud forests on Mount Lewis form the headwaters of the source of the Mitchell River. This area is home to a range of remnant and endangered flora and fauna. Bright red and blue Mount Lewis spiny crayfish (*Euastacus fleckeri*) are visible in the creeks. Endemic to Mount Lewis are the mountain nursery frogs (*Cophixalus monticola*) only found above 1,100 m and the rattling nursery frogs (*C. hosmeri*). Above 900m, cloud forests harvest condensed water from clouds that shroud the mountain. This condensate flows year round into streams and is critical to maintenance of dry season stream flows (DERM, 2012)

Cloud forest hydrology significantly enhances the ecology, soil properties and montane environment (Stadtmuller, 1987). Above this elevation, forest-leaf size, tree height and diversity decreases. The Atherton mist palm (*Lacospadix australasica*), orania palm (*Oraniopsis appendiculata*) and a type of Alexandra palm, the purple-crowned archontophoenix (*Archontophoenix purpurea*) replace climbing palms, wait-a-while (*Calamus* sp.). McJannet et al. (2007) suggest that temperature rise from global warming is predicted to cause this cloud layer to gain altitude, thus causing a loss of valuable moisture to the high-altitude forest. They determined that from 7% to 29% of total water input into forests is harvested from clouds. In fact, the ~ 6,500 mm/year runoff rate is a significant source of downstream water supply.

3.6 Resource Management of the Catchment

Environmental sustainability is, and always has been, the goal of the Mitchell River catchment indigenous population. Currently, they suffer disadvantage due to their remote location and access to income-generating industry and commercial activity. The indigenous population in the catchment is increasing, forming the dominant population group, and the largest landholders.

The industry in carbon credits created by greenhouse gas emissions may provide a solution to wealth generation for indigenous landholders. Traditionally, indigenous peoples burned land late in the wet season to aid in hunting and provide access to land. The establishment of the land tenure system and the '*sit down money*' economy caused populations to move off the land and settle in towns and communities. The outstation or bush camp initiative, popular in the Kowanyama region, allows people to re-establish the traditional burning

practices (Monahan, 2006). This aligns with scientific research which demonstrates that overall greenhouse gas emissions can be reduced in savannah lands through early targeted patch-burning techniques, as traditionally practiced (Heckbert et al., 2011, p. 51). The incentive for the Mitchell indigenous community lies in the recorded recent fire history in the catchment, which suffered from wide ranging bushfires in the absence of historical indigenous patch burning.

NGRMG and DAFF are actively promoting the Commonwealth's Carbon Farming Initiative (CFI) and researching the possibility of carbon sequestration in savanna land grazing within the catchment (CFI Factsheet, 2012, p. 1). Indigenous landholders are included in the program through an incentive to participate in the savanna burning project. In this incentive, indigenous landholders may claim tradeable carbon credits through activities such as feral animal control (emissions reduction), carbon storage inland through forestry initiatives and the traditional early season fire regime. Land managers who participate in the initiative can generate carbon credits, which can then be traded in the market place. Unfortunately, only a few methodologies have been approved. Initiatives provided for example include:

- *Reforestation*
- *Revegetation*
- *Native forest protection*
- *Avoided de-vegetation*
- *Managed regrowth*
- *Reduced methane emissions from livestock*
- *Livestock manure management*
- *Management of feral animals*
- *Reduced fertiliser emissions*

- *Increased carbon storage in soils*
- *Biochar application*
- *Rangeland restoration*
- *Savanna fire management*
- *Reduced emissions from burning stubble and crop residue*
- *Reduced emissions from legacy landfill waste* (CFI 2012, p. 1).

Savanna burning is one methodology approved for implementation but of note within the CFI is the qualifying term *'additionality and common practice'* that limits carbon offsets to those proven to occur due to the CFI. Indigenous landowners on substantial areas of land with a tradition of caring for their country and avoiding practices that release carbon into the environment are disadvantaged because their land management practices existed millennia before the CFI was introduced. Another term, *'permanence',* requires that sequestrated carbon storage be maintained for 100 years, therefore landowners are responsible for carbon released by fire, drought or clearing and are obliged to restore carbon stock. However, Macintosh (2012) submitted a commercial law opinion, in which he advocates extreme caution in dealings and contracts within the CFI. This is due to present political uncertainty on carbon policy as well as the existing national and international legal agreements and accounting structures already in place. The Commonwealth Government's (2014) repeal of the Carbon Tax gives support to this advice.

Campbell et al. (2008) have identified specific issues for which regional bodies are responsible under climate change impacts. Core issues are vegetation, salinity and water quality, and invasive species. The most significant responsibility of regional bodies is that of vegetation management. Over-clearing, overgrazing and an unstructured fire regime are all

issues that those affected can address.

The NGRMG, one of 56 management groups Australia wide, covers most of the Mitchell River catchment with the Terrain and Cape York Natural Resource Management Groups (Figure 16). Importantly, due to climate change, the criterion is to encourage biodiversity and conservation outside of the formal National Park, wildlife and conservation areas and especially on private and leasehold land. As mentioned earlier, Brooklyn Station is one of many private biodiversity rich areas set aside for conservation. Invasive plant species may survive in the environment as 'sleepers' and expand their range when shifts in climate occur. Fire management is believed to be critical to allow existing biodiversity to have a capacity to resist damage.

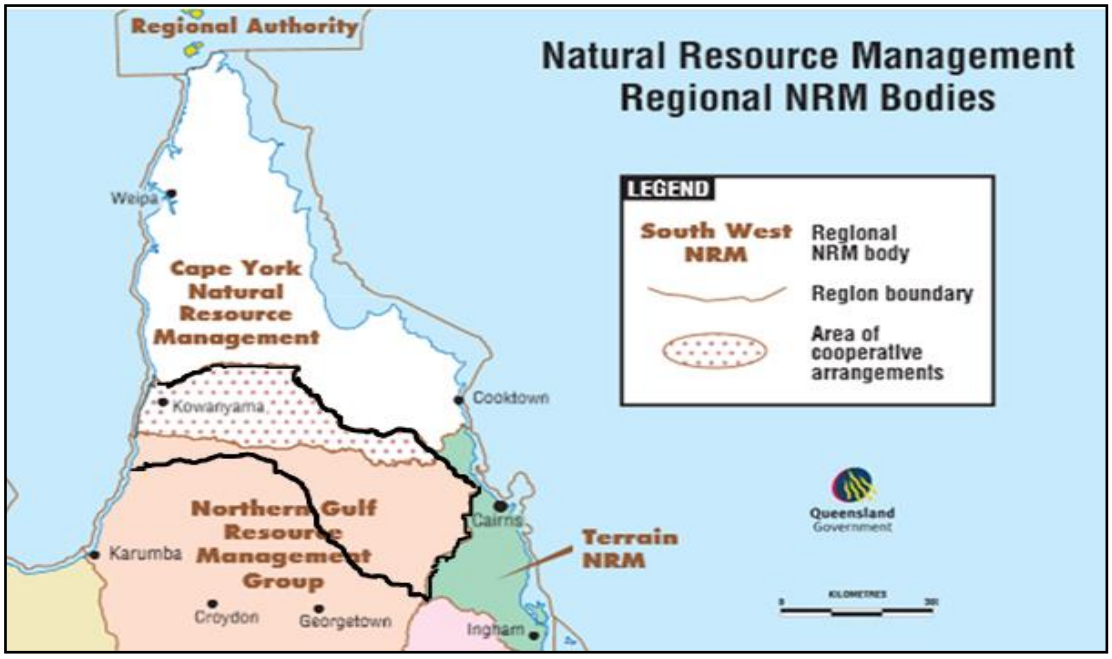


Figure 16 Natural Resource Management Regional Bodies

(Source: DERM, 2010)

The NGRMG based in Croydon is a federally-funded not-for-profit community-based Land Care organisation, charged with promoting environment, economy, social and cultural interests. The Cape York and Terrain NRM's operate north and east of the catchment. They

introduced the innovation of Grazing Land Management in 2008. This is designed to assist and encourage graziers and land managers to maintain profitability through best practice while maintaining and improving the environment. This is achieved through gaining and applying required knowledge and skills to maintain control of pest weeds and feral animals, erosion control, riparian rehabilitation and fire management. The planned outcome of projects such as these, in combination with others, should result in improved and sustainable productivity. The benefit to the ecosystem's condition is from rehabilitation and protection.

The NGRMG Plan (2008, p. 1) is presented as a compilation of local solutions developed by local scientists, graziers, farmers, fishermen, miners, traditional owners, tourism operators, conservationists, and local government who worked together and planned for natural resource management tasked to secure the health of the economy, society and environment for future generations. Fifteen new projects were proposed by the group. The most important proposed projects were listed as heavy metals, primary school resources and weed and pest control NGRMG Plan (2008, p. 14).

The effectiveness of one NRM functioning was evidenced in seeking assistance from governments and aid agencies to assist graziers following the disastrous November – December 2012 bush fires which burnt out the Gulf Plains area. This fire started near Georgetown, spread out, then moved northwest to the gulf coast past Kowanyama (Stickley, 2012; NAFI, 2012, Figures 3 and 4).

The resource management group (RMG) with specific responsibility for the catchment is the Mitchell River Watershed Management Group (MRWMG, Figure 1). Formed in 1990 and funded through the Federal Government's *'Caring for our Country'* concept, it has

community-based interests in the welfare of the environment and industry for the area. This group consists of both interested individuals and groups (e.g. shire councils, government departments, industry and environmental bodies) who meet on a regular basis to determine and implement policy and form recommendations to local and state government. The activity level of this group is seen to vary over time, due to funding cutbacks and changes in particular interests affecting the catchment. Their achievements have included rehabilitating degraded sites, pest weed and animal management, and significantly raising community awareness through education programs in schools, the goal being to create a cooperative, community-wide awareness of balanced, ecologically sound and sustainable development. The vibrancy of this group was evident at the March 2013 meeting by the number of interested parties represented to review and modify the Catchment Management Plan produced in 2000. The 12 primary goals formulated in 2000 were revisited, assessed for relevance, amended and modified to indicate progress or identify emerging issues that have arisen over time for specialist groups concerned with mining rehabilitation, tourism and recreation, grazing, fire management, nature conservation, fisheries management, weeds and feral Animals, land degradation, cultural heritage, water quality and quantity, and intensive agriculture. The current projects include:

1. Pollution control and rehabilitation from the disaster that occurred at the Baal Gammon Mine in March 2012 when contaminated water escaped from previous workings at the mine. Discharge water at the tunnel entrance was recorded at pH 3.6 and polluted with heavy metals, which drained into Jamie Creek. A failure of a tailings dam at the nearby Kangara-operated mine in February–March 2012 released a quantity of contaminated water into the creek

2. Farm efficiency and economics program to promote soil health, carbon sequestration and water management.

3. Intensive agriculture workshop that considers water efficiency and soil moisture on the irrigation area.

4. Weeds and feral animals' workshop.

5. Grazing industry workshops both at a central location and on four catchment grazing properties.

Climate change is expected to provide the climate variability needed for pest weed spread. Unfortunately, little literature on the impacts of pest weeds on the catchment affected by climate change is apparent. Over 2,700 exotic plant and 73 exotic animal species have been introduced into Australia since European settlement. The MRWMG (2014) determined that distribution of weeds in the region is closely associated with human activity. Any proposed development therefore would need to assess this threat. Rubber vine, a native of Madagascar and introduced as an ornamental plant, established itself in the catchment causing significant damage to the environment and economy (MRWMG, 2014). For control the Department of Natural Resources introduced rubber vine rust fungus in 1995. The fungus has had an impact on the control of this plant through defoliation and reducing the flowering rate. This then allows increased grass growth adjacent to the rubber vine which when burnt destroys the vine and reduces its footprint (Tomley & Hardwick, 1996). The distribution of weeds in the region is closely associated with human activity, hence any proposed development would need to assess this threat. Parthenium is spreading into the region. The NGRMG has constructed a wash-down bay at Mount Surprise and Lakeland Junction, with planning underway for a facility at Chillagoe. This is in response to concern shown by the community about weed seed spread particularly under the threat of climate change. Aquatic pests and weeds would have the potential to threaten biodiversity, especially if new water storages cross catchment boundaries. Many introduced pests and weeds exist in the eastern draining

catchments with few penetrating the western catchments so far. Invasive pest species such as Tilapia, Salvinia, Cabomba and Hymenachne all exist in the eastern draining catchments and the imperative is that spread into the Gulf region be prevented (CSIRO, 2004).

Climate change impacts on the catchment environment are expected to be increased periods of drought, increase in precipitation over a shorter duration, change in fire regime, increase in the frequency and duration of heat waves. These effects are expected to provide opportunities for some pest animals to thrive, Northern Gulf Grazing Lands Regional Assessment (2015, pp. 28–32) Pest animal species found in the catchment are pigs, cane toads, horses, deer, donkeys, goats, cats and dogs. Pigs and dogs are declared pests under the *Rural Lands Protection Act 1985* requiring landholders to control their numbers (MRWMG, 2000, p. 29). The impact feral animals have on the environment varies between species and locality. While pest animals may be a resource in one area, they are at best a nuisance in most areas and at worst a significant economic and environmental threat. Strategies for pest animal management must consider many factors if they are to be cost effective and worthwhile. Management of pest animals needs an integrated approach, research to allow informed management decisions and consideration of environmental and economic factors. Ideally, any program will need to identify acceptable pest population levels and then work towards that goal. Complete pest eradication is seldom achievable and even less likely to be acceptable when weighing costs against benefits. The likelihood is that each priority species will need separate strategic plans and that an adaptive management approach will be necessary (MRWMG, 2010, p. 29).

Without baseline information, pest animal control strategies are difficult to formulate. Current information on pest animal distribution is sketchy and very poorly documented.

Collecting information on most pest animal species is difficult because the Mitchell River catchment is so large and sparsely populated by humans and little scientific research has been done in this area (NALWSR, 2009, p. 12). Strategically, the Kowanyama Aboriginal Land and Natural Resources Management Office (2012, pp. 1–24) on the receipt of funding has implemented:

1. A pest animal management program focused on the control of pigs, cats, dogs, and corellas.
2. The Wetlands Management Program, ongoing water quality monitoring training, and aquatic weed control of Hymenachne infestation.
3. The Para grass infestation management program, which set out to identify, photograph and map para grass infestation for future monitoring.

Authorative literature predicting the impact on feral pest species from climate change is not evident for the catchment. However, as climate and vegetation change, it is reasonable for opportunistic pests to occupy (for them) the more favourable environment and niche opportunities.

Gully erosion is an issue across the catchment and is suggested to be one that can only be made worse by climate and land use changes (MRWMG Strategic Plan, 2013, p. 4). Soil erosion in the lower catchment has been studied by Brooks et al. (2009), who have contributed valuable information on the source and causes of sediment load. Their assessment in the lower catchment revealed that along 5,560 km of river frontage, active gullying is occupying ~ 0.4% (129 km^2) of the 31,000 km^2 of the area studied. They distinguish between the various examples of gully formation and found in their study area a secondary cycle of erosion into the fluvial sediment before conversion into sedimentary rock. The researchers hypothesise in their conclusion that the changes in vegetation cover

since European cattle were introduced in the 1880's, settlement is due to grazing of the riparian area and changes in the fire management. Shellberg (2010) extended this research to identify that the scarp retreat is 0.34 m/year across 24,485 m of gully front, while historical air-photo data (1949 to present) displays a 0.24 m/year retreat along 46,735 m of gully front (Figure 17). Applying the process of '*negative-exponential rate in fluvial geomorphology'* revealed that most of the gullying occurred between 1880 and 1950. Utilising optical stimulated luminescence of buried sand grains and tree ring analysis, Shellberg (2010) was able to verify the relatively young age of the gullies. This evidence is applied to support the hypothesis that the contribution of grazing intensification along the riparian zone contributes to the gullying. This alteration to land use combined with pest weed and changing fire regime has resulted in the decrease of perennial ground cover on steep creek and river banks. This has created an unstable environment which has degraded the most productive environment into an eroded landscape, depositing twice the pre-European quantities of sediment into the Gulf.

Figure 17 Annual gully scarp progression 2005-2007

(Source: Brooks et al., 2009, p. 11)

3.7 Water Resources and Land Use Potential

Water resources and land use potential in the region are under consideration in the developing climate change scenario (CSIRO-BOM, 2014, p. 6; Webb & Stokes, 2012, p. 5). They suggest that the possible increasing variability in the rainfall cycle will affect soil moisture, stream flow, and the storage level of the aquifers. However, the agricultural area of the catchment is expected to experience a lesser impact from climate change than southern, temperate areas of Australia where predictions are for rising costs and a decrease in production. The northern agricultural zone, therefore by default, may rise to the opportunity and supply southern markets when they experience supply problems from climate affected production areas. Strategies promoted by Stokes and Howden (2010) suggest that at enterprise level:

> *...adaptive capacity can be enhanced by*
>
> *(1) managing climate risk and uncertainty;*
>
> *(2) planning, learning and reorganising for climate-driven change;*
>
> *(3) building flexibility to absorb the costs of change and experiment with options for the future;*
>
> *(4) developing the capacity for individual evaluation of climate change adaptations through access to climate information, expertise and technology; and*
>
> *(5) reducing dependency on the climate-sensitive resource (such as through increasing strategic skills)* (p. 156).

Water availability and supply for development were considered in the Northern Australia Land and Water Science Review (2009, p. 5). They determined a mean annual discharge of

the Mitchell River catchment at 12,457,000 ML per annum. However, stream flow variability is very high due to the dynamic climate of the north and the distinct wet and dry seasons. A proposed development would have to consider this seasonality.

There is a lack of information about soil types and their potential. Wilson and Phillip (1999) determined the limited potential of soils in the Mitchell River catchment to grow agricultural crops. While they found the most suitable soils to be red and yellow earths and cracking brown clays, these all occur a considerable distance from the main Mitchell River channel. Unfortunately, most of the soil in the catchment is poor quality with limited drainage and has potential for salinity and sodicity. Salinity risk from irrigation is particularly high in the upper reaches of the Mareeba Dimbula Water Supply Scheme (MDWSS) and potential for acid sulphate soils has been identified in the floodplain area on the western side of the catchment (NALWSR, 2009, p. 6). Any change in land use would require significant investigation into mitigation strategies to combat the effects of salinity and acid sulphate soils. There exists the potential to utilise groundwater from the Great Artesian Basin (the predominant groundwater source in north-west Queensland). However, further information needs to be obtained about quality and quantity, especially following recent work by the Queensland Department of Environment and Resource Management (DERM) to rehabilitate some equipment that has tapped this resource. It is apparent that any increase could not be large scale.

Land tenure of much of the land is held under grazing leases. Freehold tenure is mostly present in the upper reaches of the catchment. Land availability for agricultural development would require buying back these leases, as well as considering any native title claims over these areas. The NALWSR (2009, p. 6) report identified six national parks located within

the region (or crossing over its catchment boundaries), along with three local councils and three State forests. Critical to the agricultural development of the catchment is a sustainable water supply. The report referred to the CSIRO Gulf and Mitchell Agricultural Land and Water Assessment Report (2004), which had examined 13 sites considered for potential for dam construction in the Gulf region. Following economic, environmental, technical and cultural assessment of each, only two sites were deemed worthy of further investigation. Not one of thirteen sites studied was in the Mitchell River catchment (MRCRP, 2009, Ch. 26, p. 7). Consumptive water use supports a comparatively small-scale irrigation industry and small mines that vary in number from year to year. Communities, including Chillagoe and Mount Molloy, also contribute to the overall consumption of water in the plan area, while Kowanyama's town water supply is sourced from the artesian aquifer. This artesian water is also important for the grazing industry and will remain a useful asset.

Water resource development and use is comparatively limited across the MRCRP area with the most significant development being in the upper Mitchell River in the relatively large water storage, Southedge Dam containing Lake Mitchell. This can hold up to 129,000 ML of water and has remained unused since its construction as irrigation infrastructure is not installed. Southedge is the only large dam in the MRCRP area, though there are a number of small in-stream weirs that support stock watering, town water supply and small mines (CSIRO Regional Perspective, 2009).

3.8 Economic Activity and Climate Change

The Garnaut Climate Change review (2008, p. 364) summarised comparative advantages of business and communities adapting to climate change in four ways: Firstly, climate change will require a myriad of culturally appropriate responses over time.

Secondly, due to the immense range of impacts likely across Australia, it is not feasible for government to maintain existing lifestyle choices for the population of individual areas. Thirdly, because of uncertain consequences of climate change impacts, it creates difficult scenario for planning with any degree of accuracy. Fourthly, in this paradigm, the characteristic differences of impacts create the inability of any central planning agency to react promptly to local and specific issues. Most time and cost-effective adaptation would be generated by interests within the community. The suggestion is that, by applying the policy of global emission reduction from Garnaut (2008) to the Mitchell watershed scenario, this would be the best means by which this vast and mostly remote, isolated area could sustainably adapt.

Barros (2014) states:

> *In many cases, we are not prepared for the climate-related risks that we already face. Investments in better preparation can pay dividends both for the present and for the future. Adaptation can play a key role in decreasing these risks* (p. 2).

Paton (2009) suggests that in developed regions:

> *Many communities are susceptible to natural hazard consequences. While the consequences themselves cannot be prevented, their implications for community sustainability are influenced by the preparedness of the community and its capacity to mitigate and/or adapt to disruptive consequences, (its resilience)* (p. 1). The application of risk management technology allows sustainable communities to adapt and economically develop through disaster events (p. 2).

Additionally, Marshall et al. (2009, p. 153) state:

> *Adaptation processes occur across all scales from individual to community, industry,*

> *regional, national and global. Understanding the adaptation process and supporting or enhancing it at various scales will be important for maintaining effective functioning of social and economic systems in the face of climate-driven changes".*

Agricultural lands in the catchment are predicted to be affected by climate change. Climate Q (2009, p. 41) estimate that: '*for the Far North Region, temperatures may increase by 3–9 °C by 2070. Rainfall models show a decrease over this period, while evaporation rates may increase by 7-15%'.*

The majority of cropping and horticultural activity occurs in the headwaters of the Mitchell River in the Mareeba Dimbulah Water Supply Scheme areas:

> *Climate change is expected to impact this region. The fact is that approximately two thirds of the MDWSS is in the Mitchell River Catchment. On average, $119 million of agricultural production was achieved in Mareeba shire primarily due to agricultural and horticultural crops grown from water supplied by the MDWSS. Predominant crops grown are sugar cane, coffee, stone fruit and a variety of tropical fruits* (CSIRO, Regional Perspective, 2009, p. 4).

To overcome limits to growth in agriculture for the region, the needs are:

> *significant improvements to infrastructure, including transport networks, processing facilities, commodity storage options as well as general housing, educational and health requirements the reliant population would require* (p. 4).

Howden, Crimp, and Schroeter (2012) identify six enablers (Table 3) required to deliver a structured approach for climate change adaptation in Australian agriculture all of which are applicable to the industry in the Mitchell River catchment:

Table 3 Adaptation enablers

Adaptation enablers	Examples and evidence that it is occurring
Belief that the climate is changing and will likely continue to change	Surveys that show a majority of farmers think climate is changing (e.g. ABS, 2008).
Evidence that the change will affect things farmers value	Demonstrated via observation, interpretation and attribution of experienced change as well as via research including DAFF Climate Change Research Program projects and participatory action research. The majority of surveyed farmers (62%) considered that climate change had already impacted on their farms with the majority indicating decreased production (15% increased) and 55% stating that pests, weeds or disease had increased (19.5% decreased)
Options for adaptation available and understood	Many available for incremental adaptation (Stokes & Howden 2010) with some more limited exploration and documentation of systemic (e.g. Gharmani & Moore 2012) and transformational adaptations. Limited investment in new technologies including genetics.
Support mechanisms for major changes.	Support for Peanut Company of Australia expansion into the NT and Brown's Brothers to increase landholdings in Tasmania, as well as funding of adaptation research options.
New infrastructure, policies and institutions developed to support new management and land use arrangements.	DAFF drought trial building risk management capacity (DAFF, 2012).
Targeted monitoring of adaptation and their costs, benefits, and effects.	Probably being done at enterprise scale but currently no clear systematic approach. Some experimental national scale tracking of adaptive capacity and vulnerability (Crimp et al., 2012). A component of monitoring in some research activities but the duration of these is insufficient for long term improvement. Some clear examples of learning by doing (e.g. Jakku et al., 2012).

(Source: Howden et al., 2012, p. 42)

The MDWSS area has and is facing difficulty establishing a financially stable agricultural base (Rolfe, 2012, pers. comm.). Projected effects of climate change are expected only to increase vulnerability. Solutions seeking opportunities for 'niche' crops are being investigated, with a few studies being conducted into the suitability of alternative crops to service potentially underutilised domestic and export markets. Any investigation would have to consider increased transport costs and the tropical climate. It is suggested that necessary studies investigating the salinity risks of some soils, as well as ecological studies into the potential for pests and diseases to develop. Moreover, further economic analysis into topics such as infrastructure is needed (CSIRO, Regional Perspective, 2009, p. 7). The

report further submitted that the dynamic nature of weather in tropical savannahs results in long periods of wet and dry weather, periods of extensive flooding and high humidity. Their opinion at that time was that few crops or horticultural crops are suited to such an environment. Because there is a very competitive international market for tropical produce, consideration into investment into crop suitability would be needed. High evaporation rates and extreme temperatures also restrict agriculture and horticulture development in the region (CSIRO Gulf and Mitchell Agricultural Land and Water Assessment Report, 2004, p. 6).

The Regional Perspective Paper (2009, pp. 58–59) investigated the concept of further agricultural development of the region west of Mareeba in the Mitchell catchment. Following the construction of Lake Tinaroo in the 1950s the establishment of the MDWSS enabled this area to produce crops such as sugar cane, mangoes, coffee, peanuts, vegetables and other tropical fruit. This irrigation project is in the eastern parts of the catchment closer to road and rail facilities. Any other large-scale development in the region would have to be located significantly west of this location, an area with significantly poorer soils. This means that the development would be further away from the necessary infrastructure and markets. Unfortunately, there are limits to access water supplies and these factors tend to inhibit commercial success. In addition, new and expensive water infrastructure is required and the consideration of the cost of this compared to the potential gains from returns generated by agricultural commodities may significantly reduce its economic potential.

It is suggested that, unlike many catchments in Australia and due to the undeveloped nature of the region, there is opportunity to protect and properly manage vast areas of the Mitchell River catchment for economic growth, as well as biodiversity values. However, realistically,

the dynamic and harsh climate make few crops suitable to the area due to long periods of irregular wet and dry weather combined with high humidity in summer and very high evaporation rates. Feral pests and diseases also flourish in tropical weather. In conclusion, the report determines that the possibilities for development in the north are wide and varied:

> *...concepts should be developed with significant engagement with local communities to identify risks, constraints and any potential environmental impacts* (CSIRO, Regional Perspective, 2009, p. 5).

3.8.1 Mining

The mining industry is suggested to be an important enabler for climate change mitigation on the catchment. Being less exposed to adverse market and climatic conditions that may affect primary industry, mining is (as indicated by findings from this research in Chapter 5) and has been, an alternative or primary income stream for many primary producers in the catchment. Mining has been a major industry and an integral part of this community for more than 120 years and is considered to be the oldest non-indigenous land use industry in the catchment. Gold was discovered on the Etheridge (1870), the Palmer (1873) and Hodgkinson (1876) goldfields. The arrival of the railway to Chillagoe led in turn to the establishment of Mareeba, Mungana and Almaden (Wegner, 2009).

Currently, the largest working mine in the region is Kagara Mine (2010) near Mount Garnet. Recent mineral discoveries have included perlite, mined near Chillagoe. Small scale alluvial and hard rock gold and tin operations remain with larger scale mines such as the Red Dome (now closed) and Mount Carbine (recently reopened). A typical activity occurs when miners exploit reserves as resource prices rise and down-line processing capacity becomes available. There are over 3,000 historic mining operations listed for this catchment. Current

mining activity is focused on Kangara and Baal Gammon Mine at Watsonville and Mount Garnet. The currently-mothballed Chillagoe-based mines are strategically located along the Palmerville Fault, the source of rich mineralisation.

Mine management in this region involves a dialogue concerning waterway and riparian vegetation protection, waste rock management and mine site rehabilitation, with a conflict of interest between water users. Vehicle access and exploration clearing is the most widespread visual impact of mining. Some areas of past intense mining activity now appear to be a maze of eroded access tracks. However, a legacy lies in the benefit to tourists and property owners who use these tracks to access very rugged terrain, which would have been inaccessible before. Graziers utilise mining tracks and dams for stock management, however seasonal rainfall causes severe erosion if these are not maintained or rehabilitated. Miners are responsible for environmental impacts while mining tenure is current. After mining, the Department of Mines and Environment may allow certain infrastructure such as water supply dams and access roads to remain. The process requires written consent from the background landholder who is then required to assume responsibility for these (MRWMG, 2000). Mining rehabilitation is a goal of the MRWMG Regional Plan (2013, p. 9):

> *'Environmental harm from past, present and future mine sites is minimised by implementing best management practice and technologies and ensuring effective, progressive and closure rehabilitation.'*

Abandoned mines present a potential for ongoing environmental impacts, some being registered as contaminated sites. There are two registers listed for contaminated land. CSIRO (2013) studied the national mining industry's adaptation to climate change. The findings were that only 15% of miners were undertaking climate change activities whereas

45% of their Local Government Areas was undertaking mitigation strategies (CSIRO, 2014, p. 2). Education and certification may change the mining industries perspective on climate change.

3.8.2 Tourism

The tourism and recreation goal from the MRWMG Regional Plan (2013, p. 9) is: *'A sustainable tourism and recreational industry that maintains the natural integrity of the catchment.'*

The research survey for this study determined that tourism is a valuable climate change mitigation enabler for the catchment and is currently providing economic diversification both in towns of the regions and with some catchment landholders who can supplement their income with guiding, hospitality and accommodation enterprises. The survey of the catchment identified many instances where tourist operators found a niche and have settled, invested and created enterprises, thus contributing to the economy. The major tourism attractions in the catchment are:

- Bird watching in the Julatten area
- Chillagoe Caves and historical mines e.g. Mungana
- Quinkan Reserve
- Savannalander tourist train trip (Plate 2)
- Palmer Goldfield Resources Reserve

(Department of Natural Resources Mines and Water, 2006, p. 31).

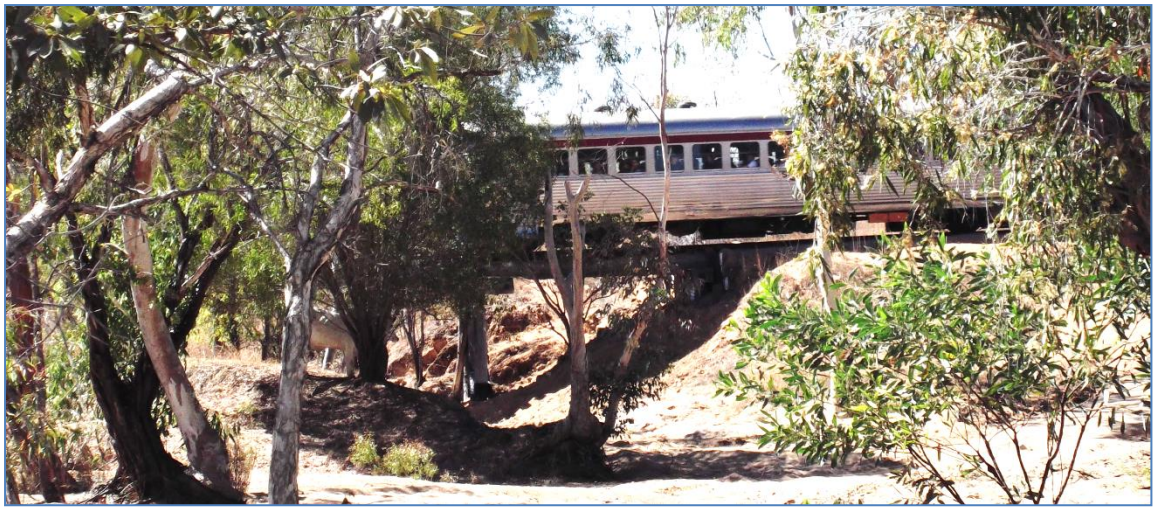


Plate 2 Gulf Savannalander tourist train on the Tate River crossing near Almaden, North Queensland. (Source: R. Beasley)

In addition, there is potential to develop low key tourism near waterholes and distinctive river features. These would cater for the fishing/four-wheel driving market. At present, there is a lack of even basic campgrounds with facilities in the catchment (MRCRP, 2009). However, the suggestion is made from this research that an important section of the tourists visiting the catchment desire to camp in unimproved sites. Typically these tourists utilise 4WD vehicles towing camper trailers or off road caravans. They desire to be self contained, self sufficient and able to utilise sophisticated equipment to provide for a high level wilderness lifestyle.

3.8.3 Pastoral Production

This major industry in the catchment is predicted to be adversely affected by climate change. Marshall et al. (2010) suggest that:

> *(1) the effectiveness of adaptive responses will be influenced by the operating context within which responses occur (e.g. the policy and governance setting),*
>
> *(2) the availability of effective adaptation options, and*

(3) the capacity of individuals to access support and implement adaptation options (p. 153).

The Mitchell River Watershed Management Plan (2000) section on grazing management has summarised the pastoral production or grazing of the catchment. Grazing from native pastures is the most extensive land use within the region. Historically, there have been scattered, relatively small-scale mining activities and supply of beef to communities created a need for the industry. Grazing properties in the region need to be large, due to nutrient-poor lands, therefore requiring a larger grazing area per beast. River frontage provides the most nutritious fodder where fertility is greatest. This region with its isolation, poor infrastructure, transport limitations and extended dry and wet seasons is one with many challenges. Development of live cattle exports from Karumba created positive expectation in the industry which ceased temporarily during the live cattle export ban of 2011.

The management group has identified property and stock management as significant environmental issues requiring attention. Grazing pressure can cause degradation of soils, loss of grasses and ground cover. Vehicles servicing the properties lead to track erosion. The narrow bands of fluvial soils deposited along the river banks provide the primary source of phosphorus sufficient soils for the region so are critical for cattle growth and fertility.

The MRWMG, (2014) advocates sustainable grazing and land management practices. The group recognises the catchment can only offer low density grazing unlike other areas in Queensland. The outcome of one group of producers is the establishment of a Local Consensus Data Group (LCD), comprising producers, government agencies and specialists with the goal to establish sustainable land use and grazing management practices across the region. Recreational pig hunting, pests and weeds do not respect property boundaries and need to be incorporated into property management as do indigenous and non-indigenous

cultural and heritage sites (Mitchell River Watershed Management Plan, 2000).

Nääs et al. (2010) draw a comparison to similarities between Brazil and the beef industry of tropical Australian savanna as it relates to the relationship of the nutritional value of native dry season pasture to the increase in ambient air temperature. Brazil has 206 million head of cattle, with 97% reared on native and/or planted pastures (Nääs et al. 2010, p. 1). The capacity decreases as a function of changes in rainfall, a rise in ambient air temperature and increase in duration of the dry season as is the experience on the Mitchell catchment. Cost of beef production in Australia at US $2.41/kg compares to the $US cost of $3.20/kg and South America $US 1.50–$1.60/kg.

Three scenarios based on the IPCC climate projections are termed pessimistic, average and optimistic (Nääs et al. 2010, p. 4). Within the pessimistic scenario, the beef cattle cost of production in Brazil may reach $US 4.16/kg, while under the optimistic scenario, the cost of production may only increase to $US 2.88/kg. These cost increases result from degradation of native pasture and the need to supplement with grain or off-farm nutritional inputs. The effects on the catchment as determined by NGRMG (2015, p. 32) are in depleted seed banks and pasture production. The effect on the cattle herds are in welfare requiring greater nutritional inputs and lower production. The mental, social and financial costs to the producers resulting from a loss of quality of life are dire. These production costs may allow producers in temperate climates to become more cost competitive and tropical beef production will lose its existing price advantage.

This link between cattle production and climate change is extended to the Mitchell River catchment as a major component of this research. The hypothesis is that an analysis

comparing animal nutrition with the dietary mix of grass and non-grass matter from tropical pastures will vary over time with climate change. For the outcome of this project to be successful the application of a specific and accurate instrument to provide reliable data over the decades of climate change variability is required. This technology was developed for tropical pastures by Coates and Dixon (2010) and was applied to the cattle selected for the Mitchell River catchment survey. This has identified the periods of dietary and/or nutritional stress that result in loss of condition and performance through the seasons (further discussed in Chapter 5). Producers provided with this information can supplement precise nutrition levels, thus maintaining condition and performance of the herd and can adapt with future climate inconsistency.

3.8.4 Fisheries Management

Effects of climate change on the fisheries of the catchment is suggested to be significant due to rising sea level, river flow changes, sediment and nutrient levels and pest invasion. One goal of the MRWMG Strategic Plan (2013, p. 12) is: *'Healthy fisheries maintained through educated management decisions.'* Within this plan a request is made for research into threats to recreational and commercial fisheries and the formulation of a plan to address the issues.

The fishing industry, both commercial and recreational, contributes to the economy of the region with the barramundi catch an important resource. It is suggested that the industry may (with management) provide a valuable climate change mitigation impact enabler with income from both recreational and commercial fishing contributing to the regional economy. The CSIRO (GMALWASR, 2004) considers the Gulf fisheries (including the northern prawn, crab and finfish industries) to be highly productive, yet one of the least

understood in Australia. The Gulf is an important habitat for many rare, endangered and threatened species, including several species of turtles, sharks and the Australian Snub Fin (*Irrawaddy*) Dolphin. Whereas an estimated 50,000 tourists (90% being recreational fishers) visit the southern Gulf, the numbers fishing the Mitchell River delta are unclear but considered relatively few, due to difficult road access, while still an important source of revenue to the Kowanyama community and regional tourism. It is suggested that major development upstream of these habitats could potentially impact on these environments and the industries they support. The CSIRO GMALWR (2004) report submits that recent studies conclude that productivity of fisheries can directly be related to freshwater flows and their quality.

3.9 Climate

The catchment, as with the rest of Australia, is influenced by the El Niño and La Niña cycles, which are a natural part of the global climate system. El Niño is a three to eight year cycle when central to eastern Pacific Ocean sea surface temperatures are significantly warmer than normal. This is associated with a strong negative phase in the Southern Oscillation pendulum and is associated with dry conditions. La Niña is the phase occurring when the eastern Pacific Ocean is much cooler than normal, with a positive Solar Oscillation Index (SOI). This phenomenon often initiates widespread rain and flooding to Australia, i.e. the events of 2009 and 2010–2011 recorded very high levels in rainfall, particularly across the western catchment (BOM, 2012).

Increasing temperature trends (Figure 18) across the catchment, although less severe than the rest of Australia, BOM (2014, p. 9), are still expected to have an adverse effect on the environment and economy of the catchment. However, the projections from the IPCC

(2013, p. 3) predict, with medium confidence, a warming rate in the near future (2016–2035) in the range of 0.3 °C to 0.7 °C in the global mean surface temperature change relative to 1986–2005. In addition, the tropical and subtropical zones are to expect greater increases in seasonal mean and annual mean temperatures over the temperate zone.

Precipitation across the catchment displays variability (Figures 19 and 20). The rainfall of 2009 and 2010–2011 (Figure 21) reinforces the variability of events over time, even though the trend displays a slight decline (Figure 20).

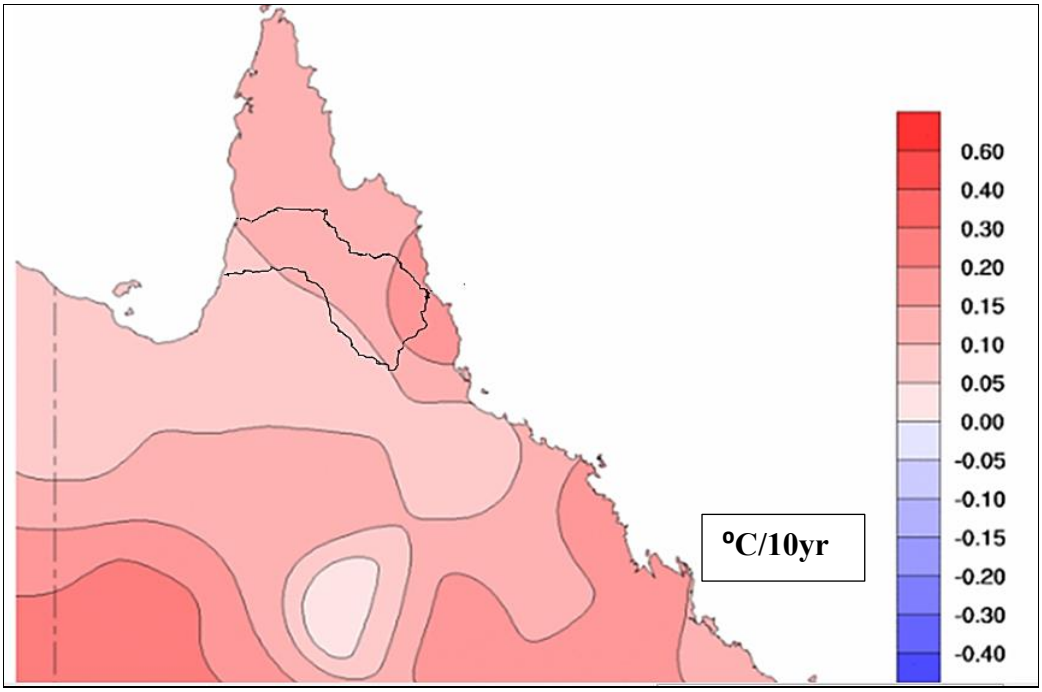


Figure 18 Mean annual temperature trends 1970–2012

(Source: BOM, 2013)

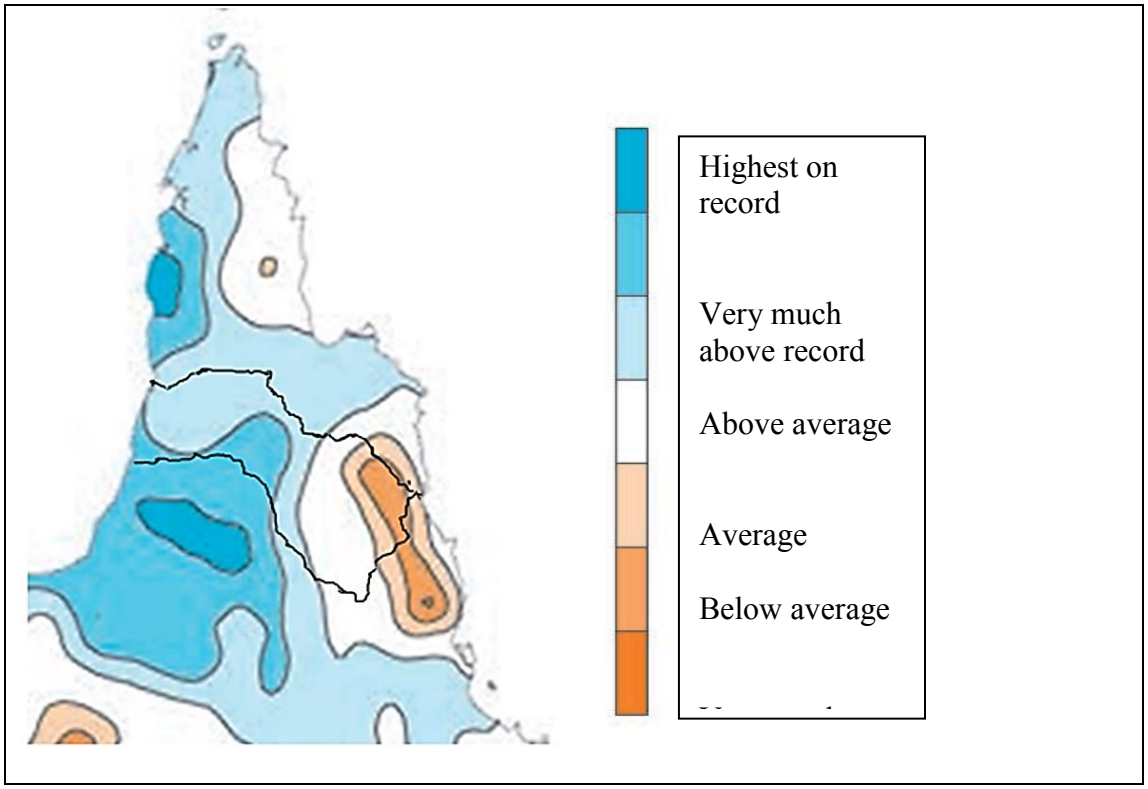


Figure 19 April to September (autumn and winter) 1997–2011 rainfall deciles

(Source: BOM, 2012)

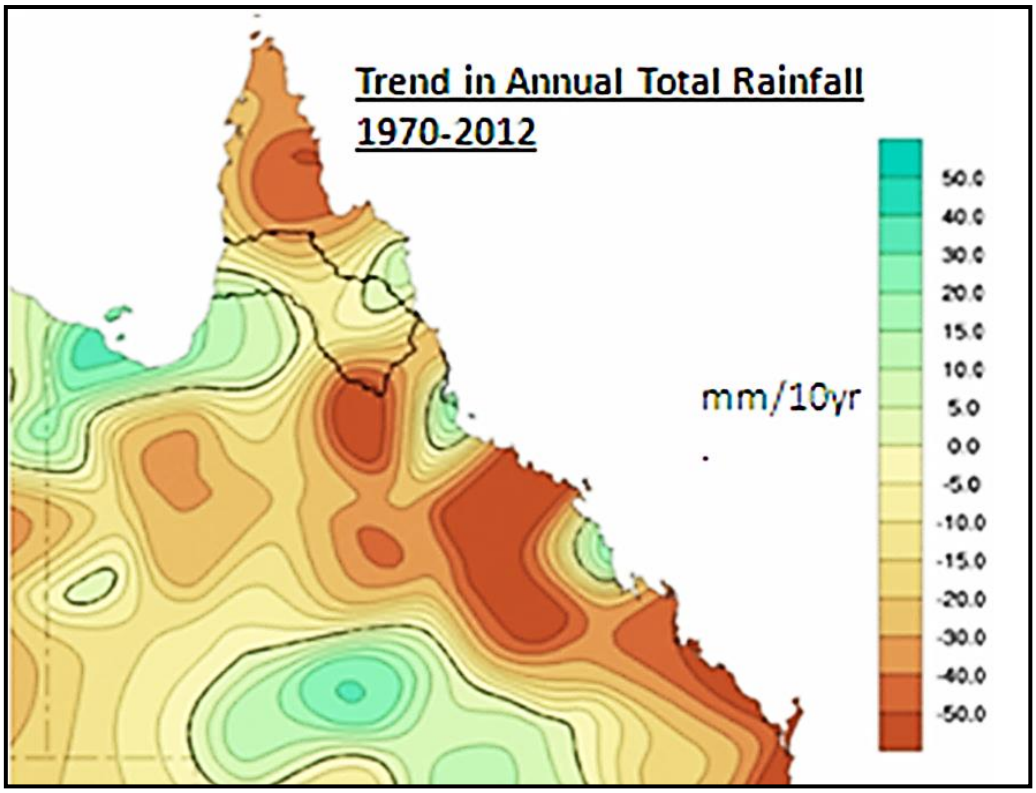


Figure 20 Annual total rainfall trends 1970–2012

(Source: BOM, 2013)

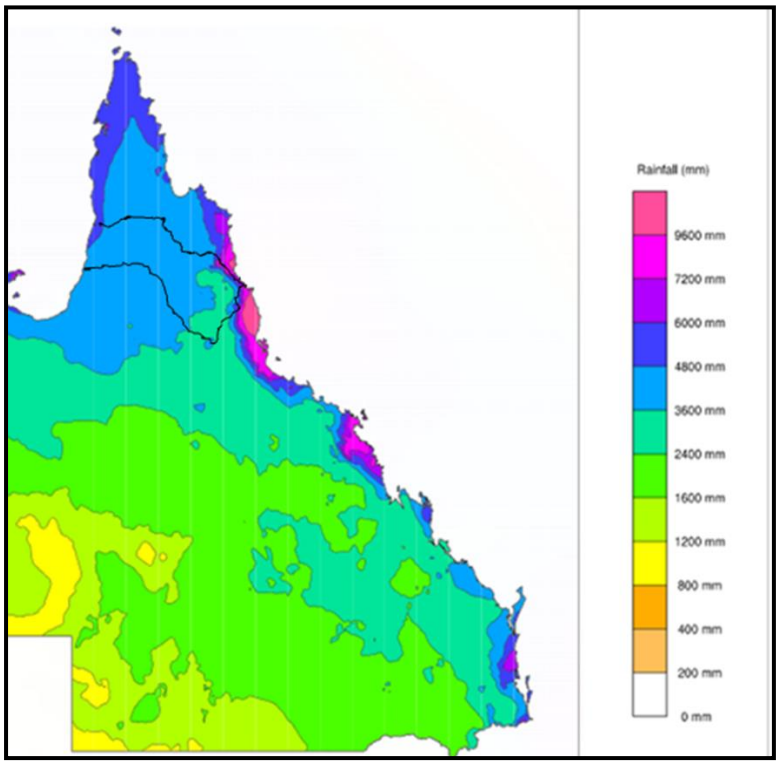


Figure 21 Rainfall totals (mm) from 1 January 2009 to 31 December 2011

(Source: BOM National Climate Centre, 2013).

3.9.1 Climate Change on the Catchment

A diagram noting the flow of effects as a result of the environmental changes caused by climate change is presented below in Figure 22. The direct flow of impacts is represented by large arrows. Indirect impacts are shown as feedback loops, all generated by the anthropogenic emissions of greenhouse gases. When this model is applied to the environment of the catchment, it is clear all elements of the biology will suffer from the effects of climate change.

Adaptation to climate change will require the co-operation and interaction of all levels of government, business and community. The definition of roles within these structures will maximise the opportunities available to, and the responsibility of the stakeholders. The Commonwealth Government's Position Paper on Climate Change Adaptation (2010, p. 4) considers that adapting to climate change is primarily risk management. It considers that

identifying and understanding risks is as critical as the allocation of tasks to those skilled to manage them.

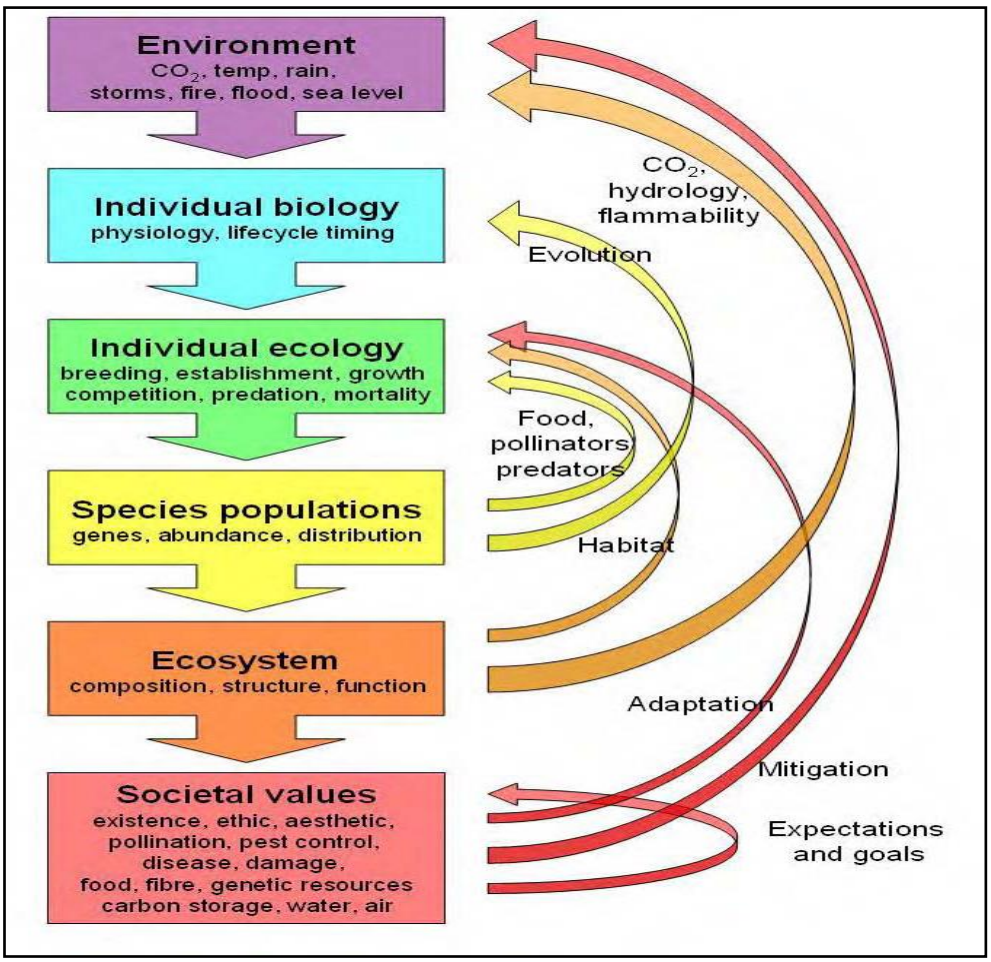


Figure 22 Schematic representation of cascading impacts resulting from environmental changes caused by climate change

(Source: Department of Climate Change, 2008, p. 27).

Therefore, businesses and community must play their part. The vulnerability of business and communities to climate change is identified as a critical new risk to the nation. The response should be that prudent businesses and communities apply due diligence prior to engaging in major new endeavours. Therefore, responsible businesses and communities will need to start to factor climate change into their everyday decision-making. At the household level, perceived and real benefits gained from adapting to climate change will provide the

incentive to take appropriate steps. This will minimise the risk of exposure to the costs and effects of climate change. The Commonwealth's (DCC, 2010) position paper postulates the notion that, as most '*assets and activities'* at peril are owned or managed by businesses and the community, it is reasonable to expect that these will take much of the national effort to adapt (DCC, 2010, p. 7). Further, the report considers it unreasonable for government to bear all the costs of adapting. It also suggests that it is inefficient for governments to make decisions on behalf of individuals and businesses that are better placed to manage their own risks (DCC, 2010, p. 7).

The CSIRO climate snapshot (2012, p. 11) predicts average Australian temperatures to rise by 0.6 °C to 1.5 °C by 2030, compared to the climate of 1980 to 1999. This warming event is projected to be in the range of 1 °C to 5 °C by 2070 provided global greenhouse gas emissions are within IPCC's range of future emission scenarios. Relevant to the Mitchell River catchment, the models indicate an increase in rainfall near the equator. Unfortunately, the models fail to provide valid average rainfall predictions over northern Australia. The models predict fewer cyclones, but the proportion of intense cyclones is expected to increase (CSIRO, 2012, p. 11).

The Department of Climate Change Position Paper (2010) on the adaptation to climate change in Australia summarises:

1. The Australian Government recognises that Australia's national interest would be met by a global emissions reduction consistent with stabilising greenhouse gases at 450 ppm CO_2 or lower. The result would limit global warming to around 2 °C (p. 4).
2. As part of a comprehensive risk assessment, the Australian government is considering the preparation required for the possibility that global agreements fail in effect. In consideration

of national, long-lived infrastructure, it may be necessary to plan for the possibility that temperatures may increase by 3–4 °C (p. 4).

3. Regionally, the north Australian tropical region response to the climate change debate was put by Howden (2008) in a presentation to the 'NT Scenarios Workshop', which was conducted by CSIRO. The effects of higher temperatures on the regional grazing industry (critical to the catchment's economy), suggest that it will reduce livestock productivity and increase cost of production. With global beef prices already low, a difficult market will result (p. 15).

At the Queensland State level, adapting to the impacts of climate change are directed at:

> *Providing information, building resilience and improving planning. Queensland needs to adapt to climate change impacts that are already occurring and that will continue to occur despite action to reduce emissions. It is essential for Queensland to develop resilience within its communities and industries to adapt to the inevitable impacts of climate change* (Climate Q: toward a Greener Queensland, 2009).

The climate projections for the catchment determined from the BOM-CSIRO 'State of the Climate' reports (2012, 2014) are:

1. Temperature rise compiled from the 1960–2011 data range from $0{\cdot}4^0$C–$0{\cdot}8^0$C (p. 3). Rainfall over the catchment in the April–September period from 1997 to 2011, has ranged from the lowest on record in the Eastern Highlands through to above average to highest in the Western Plains (Figure 19).

2. Sea level rise for the Gulf Coast recorded from January 1993 to December 2011 is greater than 11mm/yr. (Figure 23). This is the highest rate of rise on the Australian coast and considered to be two to three times the global average. CSIRO researchers are investigating

this phenomenon to provide data for planning for the region.

3. Sea surface temperatures for the Gulf coast are unavailable; however CSIRO has determined that the sea surface temperatures have increased by 0.8°C faster for the Australian region than the global average (p. 7).

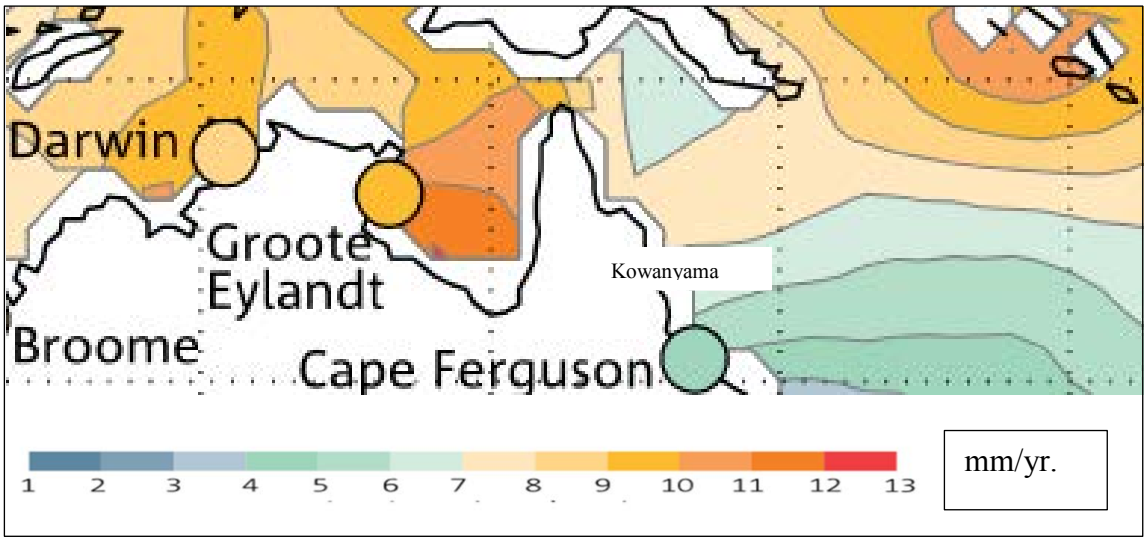


Figure 23 The rate of sea-level rise around Australia (mm/year) as measured by coastal tide gauges (circles) and satellite observations (contours) from January 1993 to December 2011

(Source: CSIRO, 2014).

3.9.2 Sea Level Rise

On the lower Gulf plains sea level rise is beginning to impact the littoral zone during storm surge and high tide events. Castillo (2009) determined that rising sea levels are causing a habitat loss for traditional freshwater food resources.

Castillo (2009) records the experience of Kowanyama elders who found that rising sea water is inundating the littoral zone and salinating the coastal freshwater swamps. The salt ingress is given as the cause for the dieback of coastal tree species. The rising sea levels are causing a habitat loss for traditional freshwater food resources. As '*Inherkowinginambana*', a Kunjen elder ponders: '*When that whole ocean comes and rises up its going to bugger everything up. All us people black and white, where are we going to go?'* (Castillo, 2009, p. 1). Castillo (2009) also quotes a community ranger who is working with the elders to protect

their Aboriginal country and culture: *'Every year, it (the tide) comes in, it goes a bit further up….once it hits the swamps, that will kill all plant life and waterways'* (p. 1).

This impact is due to the delicate balance that exists between saltwater and freshwater that nurtures life in this area. These people have relied on separate but complementary saltwater and freshwater ecosystems for drinking water, hunting and foraging.

In common with other coastal peoples in the Pacific, Castillo (2009) suggests that Aboriginal people living on gulf coastal plains and in Kowanyama are particularly susceptible to even the most minor changes in sea level. She considers that the predicted increase in tropical weather events in this flat country could mean that seasonal flooding of one of Australia's largest river systems could well occur before major sea level change.

3.9.3 Plant Community

Modelling of plant community changes as a consequence of climate change at the end of the twenty-first century is simulated by Bergengren, Waliser and Yung (2010) who applied the Equilibrium Vegetation Ecology Model (EVE) in order to determine the state of terrestrial vegetation change as a function of climate. These projections estimate the rate at which species turn over, to allow an ecosystem to stabilise with the climate. Global results indicate that 49% of the earth's land surface area will undergo plant community changes and 37% of terrestrial ecosystems will undergo biome-scale changes. Their mapping covering the Mitchell River catchment predicts that by the end of the 21st century, the area of the grasslands and forests will remain unchanged; for tall cane grasses (e.g. sorghum to spear-grass), a '*range*' of change of 50% is predicted; while short-bunch graminiods (grasses, sedges and rushes) cover can expect a change by up to 10% in the varieties present (p. 3).

3.10 Local Government

Regional action on climate change will substantially be enacted at the local government level as this level will hold, or will be able to hold, access to resources and facilities to address emerging issues. The catchment falls within the local government areas of Mareeba, Cook, Etheridge and Carpentaria Shires. Townships within the catchment are Mount Molloy, Julatten, Mount Carbine, Chillagoe, Kowanyama and Almaden (Figure 24). Local government administration for the catchment being spread out between these councils presents difficulties at a catchment level. The public therefore require specific information on their location so as to determine the respective council to contact for services. The indigenous population is primarily concentrated in the Kowanyama Community.

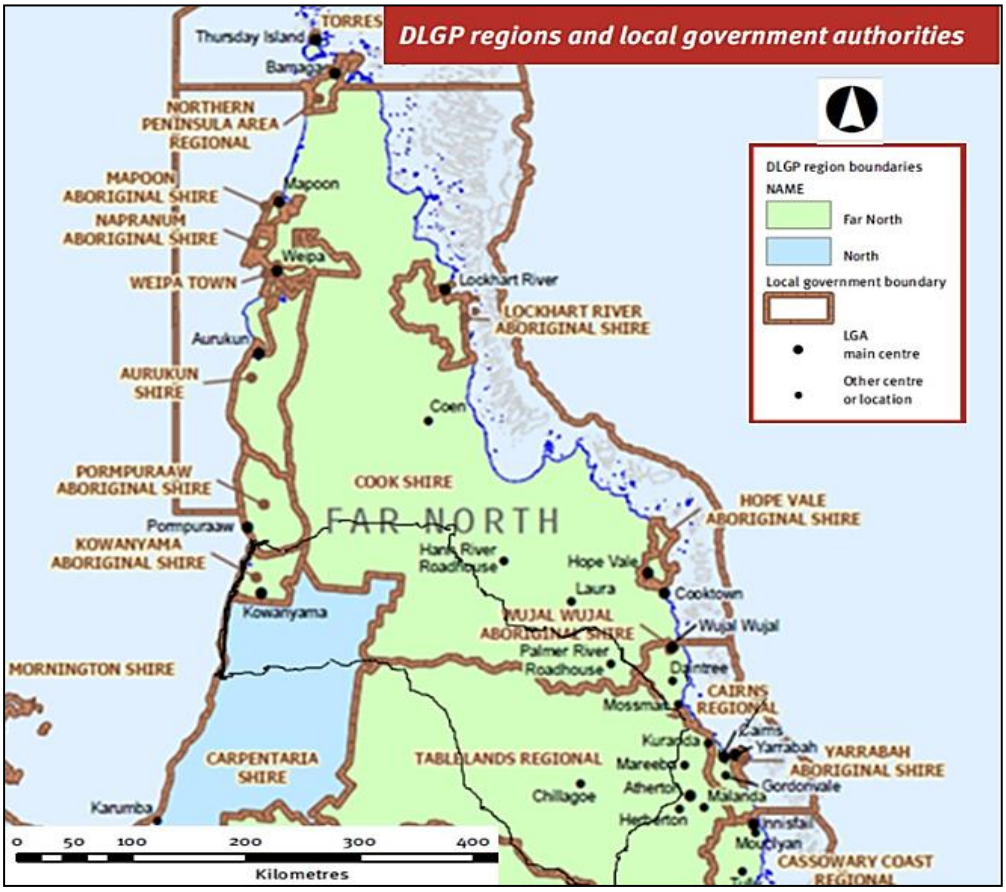


Figure 24 Department of Infrastructure, Local Government and Planning (DLGP) regions and local government authorities

(Source: Queensland Department of Infrastructure Local Government and Planning, 2015)

3.11 Land Use

The 15,425 km length of the Mitchell River and tributaries allow movement of food, nutrients, soil, organic matter, plants and animals.

> *It is one of Australia's most important and least disturbed river systems, wetlands and marine environments. The region forms a key link between the Gulf and Cape, in the chain of relatively intact landscapes. The area is also of great cultural significance with a rich Aboriginal cultural heritage* (Cairns and Far North Environment Centre, 2014).

The catchment is composed of primarily grazing land consisting of large family and company-owned grazing leases and the DOGIT (Deed of Grant in Trust) of Kowanyama Aboriginal community. Indigenous people own several holdings in the catchment, including Kondaparinga, Bulimba, Bonny Glen, Oriners, Powis and Sefton and the freehold areas of Southedge Station, part of Wrotham Park Station and many smaller blocks in the east of the catchment (MRWMG, 2014). Intensive irrigated agriculture is located along the MDWSS area and the Maryfarms and Julatten localities. Conservation areas set aside for National Parks are the Errk Oykangand National Park (formerly Mitchell and Alice River National Parks), Chillagoe, Mungana Caves, Bulleringa (part), Forty Mile Scrub and Hann Tableland. The only major water storage is the unused Southedge Dam (129,000 ML) located north of Mareeba (CSIRO NASY, 2009, pp. 355–360).

3.12 Conclusions

Because the Mitchell catchment is being affected by climate change, this chapter set out to describe the region, to explain how and where the impacts can occur. The CSIRO-BOM State of the Climate Report (2014) continues to record the changes in the Australian climate. For the Mitchell River catchment, results indicate mean temperature has increased

by 0.9 °C, with temperature projections rising by 0.6–1.5 °C to 2030, and rainfall through the wet season (October–April) is in the 10+ decile range recording areas of the highest in records. The dry season (May–September) is the same except for the Mt. Windsor, and Mt. Lewis National Parks area, which continues to record below average dry season rainfall (pp. 6–7). Rain events are predicted to increase both in frequency and intensity (p. 15). This is the third of the biennial climate reports and the scenarios proposed only add to the gravity of the effects of climate change on the catchment as discussed previously in this chapter. This literature review provides evidence to support the proposal that an initial response needs to be in disaster preparation and mitigation implementation. Consequently, the literature was searched to identify and catalogue possible adaptation strategy proposals. The first task undertaken along this direction was to investigate the rationale for a catchment study. The concept adopted is promoted by Wilby et al. (2006) who determined that the environment of a catchment is determined primarily by its hydrology. The decision to select the Mitchell catchment for study is found on its location at the base of the Cape York Peninsular and because it acts as a line dividing the bio-diversity of the cape with the North Australian continental ecosystem. Because it is relatively undeveloped, and the catchment hydrologic flow is to the north-west it provides an ideal line to control and/or limit the movement of invasive pests, weeds and disease to and from the Cape. Consisting of five major bio-regions the catchment spans from the temperate Buna Pine forest on the western slopes of the Mt Lewis cloud forest across to the high protein rice grass plains on the Gulf coast (MRWMG). The rivers flowing into the Mitchell contain many permanent waterholes which provide wildlife refugia during the dry season when river flow ceases. Sediment accretion from mining, land clearing for agriculture and grazing pressure poses an issue for concern and action during the climate change events.

A disparity is faced by the population statistics of the catchment because they are situated across statistical boundaries and interpolation of data was necessary to appreciate the nature of the population. This revealed the demographic characteristics of the catchment (Ch. 3.2. – population 5,252) and describes the disparity in age and composition from the Eastern agricultural zone to the Indigenous population centred on Kowanyama. The data clarify the Australian rural phenomenon of the exodus of young people in the 15–35 yr cohort who leave to seek education and work. The census data illustrate the significantly lower household income both in the indigenous and non-indigenous community of the catchment when compared to the Australian average. The high cost of living in this remote area places residents at a distinct economic disadvantage. Climate change impacts on the catchment population may affect the human health and disease burden. Sea level changes and rainfall variability are affecting the traditional outstation lifestyle of the Kowanyama community. The literature review (Section 3.1) reported on community issues from a telephone survey arranged by the NGRMG. The findings were useful to compare with research conducted across the catchment during field work.

Information on the range of natural resources of the catchment and the impact climate change may have on them has been sourced from the literature. Promoted as an important climate change adaptation strategy the Australian Wildlife Conservancy's Brooklyn Station located in a unique area of flora and fauna diversity. This destocked former cattle station has been dedicated as a wildlife refuge which has the sustainable capacity to be resilient to climate change impacts while contributing to the economy as an eco-tourism venture.

The literature described the importance subterranean insects such as ants have on the sustainability of the forests and grasslands of the catchment by conveying and storing seeds

while improving the quality of the subsoil. The importance these life forms have in adapting the flora to climate change is currently the subject of research however they are expected to sustainability contribute to the resilience of the ground cover.

The literature provided information on environmental issues threatening the resilience of the catchment facing climate change such as siltation, gully erosion, salination of streams, polluted mining discharge, pest weeds and animals, changes in the fire regime, overgrazing and grazing on the riparian zone. The numerous natural and historic features apart from the river and lagoon systems forming the Mitchell River were reviewed. These add to the sustainable economic base of the catchment and provide an adaptive resource in the face of climate change. Examples are: Chillagoe Caves, Mt. Mulligan, Mt Windsor and Mt Lewis National Parks Maytown and the Palmer River Historical Reserve, Thornborough and the Tyrconnel Mine, Gulf Savannalander Tourist Train. A valuable economic resource is the recreational fresh and saltwater fishing industry of the catchment.

The available literature on economic activity in the catchment was reviewed considering the proposed effects of climate change and the need for sustainable economic development following disaster events. For example, indigenous communities actively seek strategies to replace the dependence on welfare. From the literature one financial opportunity for the indigenous land holders across the catchment is in the carbon storage initiative which complements traditional land management practices through early seasonal burning, minimal vegetation clearing and pest plant and animal control.

Literature on mining activity in the catchment reveals a highly variable and volatile industry based primarily on exploitation of rich reserves of minerals chosen to meet a short-term

demand for a product when supply and prices are favourable. Small mining operations across the catchment provide additional income and employment for residents of the catchment. The literature details the legacy of damage to the environment of abandoned mines but also the benefit to the grazing industry that remaining mining infrastructure, such as access roads and dams (MRWMG).

The tourist potential of the catchment (a significant resource for the tropical North) was investigated considering the probability that climate change may impact the industry. Regardless of the negative impacts possible, the literature provided data on the rise in tourist potential and activity in the catchment and bright prospects for the future.

The primary economic activity in the catchment is the grazing industry. The literature provided data on the physical characteristics of land, grazing potential and economic potential. Climate change impacts are revealed to be significant and the strategies to mitigate some of the effects are described. The report of the impact of the live beef export ban in 2011 was that it created great economic and personal impact on the catchment industry (CSIRO).

The hydrological cycle is described with its natural variability in rainfall. Climate change is expected to increase this range of variability and intensity and supporting evidence is presented from the BOM data. The consequences considered on the flora and fauna and the economy of the catchment. From this review further concerns are raised on the effects of climate change on the emergence of pest weeds and animals. Erosion and sedimentation issues are reviewed and the effects of the possible increase in levels due to the intense brief periods of rainfall and longer dry periods. Sustainability and availability of the water

resources was reviewed by the CSIRO and the recommendations were that the limited supplies and the distance from suitable agricultural land prevented development of water storage and irrigation facilities.

The complex political nature of the catchment across the four shires was investigated, and concern is raised, particularly considering local governments' role in managing climate change impacts.

As climate change induced temperature rise and rising sea levels affect the catchment. The concern for the sustainability of the life form supported by the permanent waterholes resulting from predicted variability in rainfall. The same concern is reported for the plant community from the cloud forests across to the Gulf plains. This research may provide strategies to mitigate the dire scenario the literature predicts for the near future.

Chapter 4

Methodology

Introduction

This chapter describes the methodology and collection process of the physical and cultural data necessary to answer the research question. This information was obtained from: 1. A review of the literature. 2. Key informant discussions and learning from experts on catchment specific issues. 3. Catchment wide visitation and observations. 4. A survey and questionnaire of residents to obtain their opinions and experience of catchment issues as well as their understanding of climate change issues. 5. A project to provide baseline catchment pasture nutrition levels and to disseminate the climate change specific adaptation technology through the beef production community.

4.1 Data and Methodology

Dealing with the phenomenon of climate change, Howden (2008, p. 15) proposed the adoption of a *'scenarios approach'*, which has been modified and adopted for this research project. This enables researchers to consider climate change, not in isolation, but with other key drivers:

1. Consider climate change and impacts.

2. Accept the dilemma of unresolvable uncertainty.

3. Recognize the external drivers that we are unable to significantly affect.

4. Concentrate on the topics that can be changed.

5. Implement policy to accommodate as wide a range of futures as possible (p. 2).

One factor, for example, is the effect of higher temperatures on the regional grazing industry, which occupies most of the Mitchell River catchment. Both Howden (2008, p. 15)

and other rangeland specialists suggest that it will reduce livestock productivity and increase cost of production and, with global beef production prices already high, difficult market conditions may result. To investigate the research question which seeks to determine whether members of the catchment decide to initiate mitigation strategies on their own initiative, or delay action until external governmental and commercial agencies impose compliance upon them. It was therefore necessary to determine the behaviour of the community as to whether they decide to use their own creativity and co-operation to initiate a range of mitigation strategies or defer to external compliance being imposed by government and/or commercial directives. These findings will help determine the status of the community level of social capital which Cavaye (2004, p. 2) considers as: '(*1) Participation in networks, (2) Reciprocity, (3) Trust, (4) Social norms, (5) A sense of the 'common', and (6) Proactivity and co-operation*'.

To develop these issues and those introduced in Chapter 1.2 to a satisfactory conclusion, this required data to be gained primarily from:

(a) A literature review of both published research and grey literature from government departments. This included published climate data from the BOM, which is based on Australian and international climate data was reviewed.

(b) Semi-structured interviews, observations and data were gathered from residents' experiences.

(c) The creation of a database from 240 cattle faecal samples from a 2.5-year survey of pasture nutrition characteristics of the catchment savanna, utilising FNIRS technology.

After discussion with the stakeholders in this project, resolution was made on the selection of the theoretical concepts. The research model chosen was designed by AGO (2006) and

advocated by Howden (2008, Figure 25). This structure provides a feedback and reference loop within a communication, monitoring and reviewing framework. The model was chosen because it permits use of both quantitative and qualitative methods of study.

Figure 25 Adaptation in an unknowable future

(Source: Australian Greenhouse Office, 2006).

A combination of this theory and the methodological structure (Figure 26), was applied to the community architype to either self-determine their response to climate change (internally regulated) or adopt the sectoral (externally regulated) approach. The reality is that a combination of external factors i.e. anthropogenic emissions, as well as local and community strategies e.g. fire management, erosion controls etc. have already contributed to the development of resilience. This rationale is further enhanced by the inclusion of the concept proposed by Sellke and Renn (2010, p. 295) who introduce the term of *'risk governance'*, which is designed to consolidate the activities of '*risk assessment', 'risk management'* and *'risk communication'* into one structure. This approach is guided both by *'resilience as well as virtual knowledge management and exchange'*. Their concept is divided into five subsets termed '*risk governance, pre-assessment, appraisal, risk*

characterization/evaluation, risk management and risk communication'. It is suggested that their dialogue-focused organisational style model is suitable as a tool to apply to the management of overall vulnerability to the effects of climate change on the Mitchell River catchment.

4.2 Theoretical perspectives

In the Mitchell River catchment, some of the effects of the predicted change in climate will affect precipitation rates and distribution, cloud formation patterns on highland cloud forests, temperature increase and variability, sea level rise, extreme weather events and change in flora and fauna habitat and distribution. The initial response will stress the adaptive capacity of both the environment and the economy. This has resulted in the need for this research project to investigate the proposed effects and determine mitigation strategies. The quantitative type theory (Figure 26, Table 4) is designed for this study to consider the effects of climate change on the catchment resulting from emissions of man-made CO_2 and is measured by the FNIRS analysis A qualitative style theory model was planned to analyse the affected economy, culture and environment of the Mitchell River catchment as it adapts to the effects of climate change, and strives toward developing resilience.

The synthesis of the recommendations as set out in Cresswell (2003) were designed to provide solutions to reduce the vulnerability of the population, economy and environment with the goal of these recommendations leading to aid the development toward resilience and adaptation to climate change effects on the catchment.

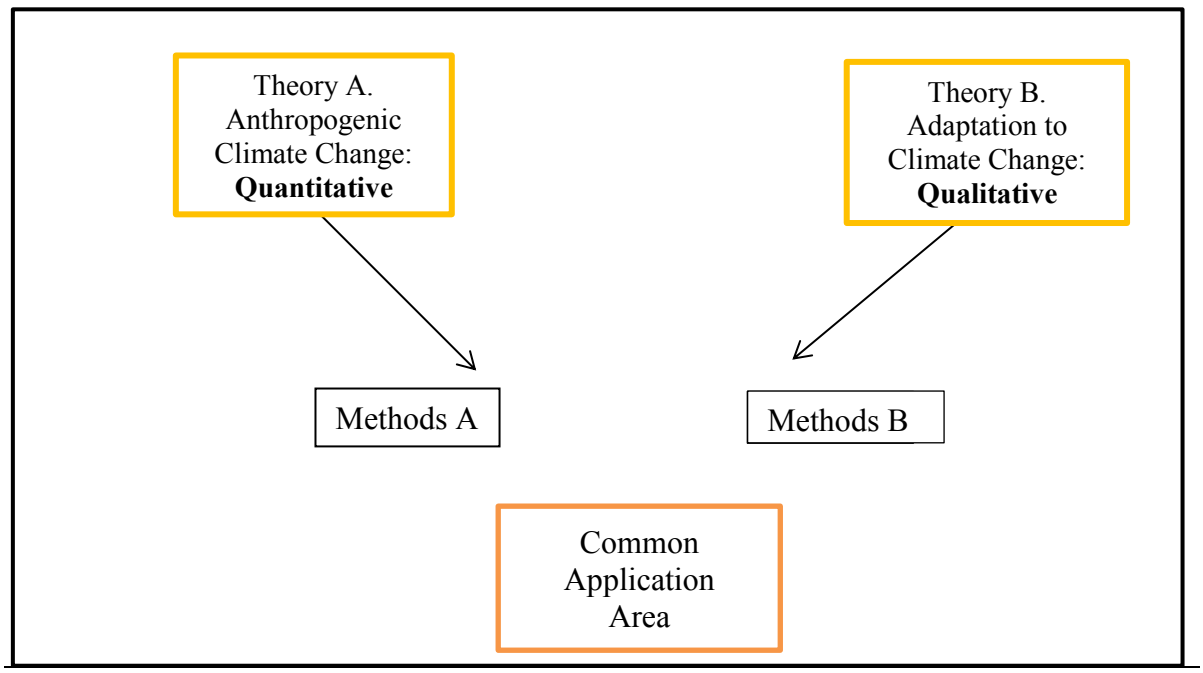


Figure 26 Methodological structure

From this theoretical premise, a methodological structure was formulated and implemented. Each of the theoretical constructs (Figure 26) was treated as independent and the combination of these multiple methods proved useful to determine a convergence or overlapping of results (Cresswell, 1994). Within this philosophy, a broad stance allowed for the wide and complex distribution of data, and the researcher has accepted the role of both observer and participant. To enable such an activity to be realised required a series of assumptions to be made, requiring a mixed-method approach (Creswell, 2005, p. 1). These are methodological, ontological and epistemological. These were necessary to answer the respective questions.

For this study all three assumptions (Table 4) were utilised. The methodological assumption was found to be a suitable tool that allows an independent and valid analysis of the literature and survey results from both the inductive and deductive perspective. The ontological assumption (Table 4) was selected because, in the quantitative state, the reality of adaptation to climate change was studied as objective, singular and separate to the researcher.

Table 4 Characteristics of theoretical constructs

Assumption	Question	Quantitative	Qualitative
Methodological	What is the process of research into the topic of adaptation to climate change in the Mitchell River catchment?	Employing deductive process; cause and effect impacts of climate change. Leading to a static research design with categories isolated before the independent study. Deductions forming predictions, descriptions and understanding. Goal is to be accurate, reliable and valid.	An inductive process seeking to supply strong evidence and categories on the effects of adaptation to climate change on the catchment. Reliability determined through verification of data.
Ontological	What is the reality of the adaptive process to climate change in the Mitchell River catchment?	The reality of the research question is to be objective, singular and separate from the researcher.	The reality of the research question is subjective and seen by participants in the study as multifaceted.
Epistemological	What is the relationship of the researcher to the research question?	Researcher was independent from the research topic.	Researcher interacted with the research topic.

(Source: Cresswell, 2003; Clarke, 2005, p. 10).

The nature of the study also required the epistemological assumption, which allowed the reality of the need for the researcher to be independent from the topic being researched in the quantitative phase, while permitting necessary interaction during the qualitative phase. The caveat to both previous questions is that the concepts studied in this research are limited by the researcher's knowledge and capacity. The literature, peer review and expert opinion were drawn on to moderate this issue (Table 5).

Table 5 Theoretical justification for research question selection

Criteria	Quantitative Paradigm	Qualitative paradigm
The researcher's world view as applied to the Mitchell River catchment.	The researcher's competency with methodological, ontological and epistemological assumptions	The researcher's competency with methodological, ontological and epistemological assumptions within the qualitative paradigm.
Training and experience of the researcher	Technical writing, computer, statistical skills	Literary writing skills, text-analysis and library skills.
Researchers psychological attributes	Competent with rules and guidelines for conducting research, low tolerance for ambiguity, time for a study of a short duration.	Competent with lack of specific rules and procedures for conducting research, high tolerance for ambiguity, time for lengthy study.
Nature of the problem, which is the adaptation to the effects of climate change	Previously studied by other researchers so that the body of literature exists, is known along with the variables, and existing theories	Exploratory research, variables unknown; context important, may lack theoretical base for study
Audience for the study (e.g. journal eds., readers, examining committees)	Individuals accustomed to/supportive of quantitative studies.	Individuals accustomed to/ supportive of qualitative studies.

(Source: Cresswell, 2003; Clarke, 2005, p. 12).

4.3 Research Procedure

Primary research was conducted in the population analysis by means of both semi-structured interviews and personal on-site observation (Appendix B). The subjects were selected according to their responsibilities, geographic location and classification of role e.g. primary producer, miner, government official, resident or tourist.

Secondary research was conducted by:

(a) a literature review (Chapter 2) of published research and grey literature (from

government and non-government agencies) of relevant topics to provide a comprehensive knowledge base.

(b) Lectures and presentations were held at JCU, CSIRO Townsville, conferences in Mareeba and Melbourne, and webinars focused either on the catchment or related issues.

(c) Interviews and discussions with experts in the economy, environment, and management of the catchment or with an interest or expertise relevant to the issues being researched.

(d) On-site observation of the environment, economy, society and infrastructure of the catchment (including 55+ years of experience of the catchment) observing changes in government policies, the economy, land use and development in the catchment.

This thesis considers that adapting to climate change is in part risk management. It suggests that identifying and understanding risks is as critical as the delegation to those skilled to manage them, therefore both business and the wider community must become engaged to work to a common goal.

The vulnerability to climate change for business and community is a critical new risk to the catchment. Responsible businesses and communities need to factor climate change into their everyday decision-making. At the household level, perceived and real benefits gained from adapting will provide the incentive for them to take appropriate steps.

Research results from data sourced from the catchment reinforce the importance of the Federal Government Position Paper on Climate Change Adaptation (2010. p. 4) study as all of the areas and topics studied in this research indicated varying moderate to severe degrees of vulnerability.

4.4 Methods and Techniques

Semi-structured and unstructured interviews were conducted (Appendix B) to ascertain the opinions and experiences of the population, visitors and administrators. Catchment-wide observations were conducted to record and/or confirm the experience and observations of others. Cattle faecal sample collection was conducted, prepared and analysed using FNIRS to provide foundational data on the savanna land characteristics across the catchment. A database was formed, from which a statistical analysis provided results that were integrated into a GIS. Selected findings were then communicated directly, in combination with DAFF extension officers, for training and preparation of individuals within the community. Other findings were incorporated into recommendations and climate change mitigation strategies for the community and government stakeholders were developed.

4.5 Research Design and Assumptions

The project assumption generally follows the determination set out in the Federal Government Position Paper on Climate Change Adaptation (2010, p. 4), i.e. adapting to climate change is primarily risk management. Risk management is the process of evaluating the severity and probability of a harmful event arising from a hazard. The process to be followed is:

a. Identify risks and their potential to cause harm to the environment.

b. Analyse the risks to determine the consequences and cost factors of an event.

c. Evaluate risks in a hierarchy of damage potential and suggest options that may be erased from the plan due to their low level of risk or outside any form of management.

d. Control identified risks to reduce the occurrence of hazard-induced events and facilitate protection for the community. Within this measure, an analysis is applied utilising a control hierarchy designed to:

1. Eliminate or isolate natural or other hazards.

2. Substitute the hazard.

3. Control-engineered e.g. fire breaks, levee banks.

4. Control with administrative or social policy.

5. Provide community and resource safety and protection.

6. Formulate a plan to best manage the expected or experienced consequences of climate change, Position Paper on Climate Change Adaptation (2010, p. 4), Howden, (2008)

4.6 Sample Collection

An example of a climate change indicator chosen for this study is a test of the floristic variety and nutritional content of savanna grazing land. This required FNIRS to be applied to faecal samples collected from across the catchment. This technology was enabled by Coates and Dixon (2004–2007) who determined the reliable calibration of FNIRS equations, which has enabled the predictions of the nutritional status of tropical pastures. The data collection for this climate change indicator is derived from beef producers across the catchment. They each selected up to four GPS recorded sites on their properties and collected a sample of fresh dung each month from fifteen cattle representing the herd at that site. The sample was mixed and dried, then sent in prepaid mailers to Townsville. Here the samples were prepared by oven drying and milling on a Foss mill to < 0.3 mm size. FNIRS samples were then assayed in a Perkin Elmer 100 spectrometer at the Australian Institute of Marine Science (AIMS, Cape Ferguson Laboratories), on a Foss spectrometer at CSIRO, Townsville and at Symbio Alliance laboratories in Brisbane, while wet chemistry phosphorus (P) testing was conducted by the University of Queensland (Gatton) Laboratory and AIMS. The results were interpreted and forwarded on to the grazier for management decisions and DAFF extension officers for their advice to the producer to assist their

decision-making processes.

Data from FNIRS analysis, rainfall, pasture description and condition were then collated and a histogram for each site compiled. This was transferred onto a map of the catchment and formed into a graph representing the nutrient condition of that particular bioregional location.

2. Primary data for the human aspects of the project were collected by means of:
(a) Ethics-approved, semi-structured interviews. The interviews were collated into their respective topics and the findings tabulated along with the relevant observations. The source of the interview data collection was from representatives of pastoral, agricultural, tourist, indigenous, cultural, environment and community organisations. The data were derived from a survey of a stratified sample of the population.
(b) Personal observations were made, analysed and recorded.
(c) Analysis of 2011 ABS census data relevant to the catchment population.
(d) Historical records and published literature concerned with the catchment.

3. Secondary data collection for the human aspects were sourced from doctoral theses, published literature, announcements/media statements and reports made by state and local government and non-government organisations and community groups. Data collections for the environmental and economic aspects were sourced from academic, scientific, governmental and company publications and reports. However, due to the scarcity of academic literature specific to the catchment, ‘grey’ literature has necessarily been sourced to support the discussion.

4. Variables in the study are identified as those in the human population dynamics. The majority of the population of the catchment are indigenous and most are welfare dependent. They have their unique culture and an abiding and spiritual relationship to the country. The primary production community is mostly managed by non-indigenous persons and actively contributes to the economy. Population density is concentrated in the far eastern section near Mareeba and in the far northwest in Kowanyama.

A variable in the geography of the catchment is in the five biogeographic regions (Figure 10), each with different soils, precipitation and climate. This leads to the other variable in the study which is the utilisation of both physical (quantitative) and social scientific (qualitative) concepts within the model (Figure 26). Both variables have been adopted due to the substance of the data and cross discipline derived conclusions.

4.7 Research Methodology and Typologies

The methodology and typologies adopted for this study are after the format of Clarke (2005). The rationale was to provide classifications, meanings and answers to the research question and was necessarily multidisciplinary in nature. These and their relative examples are:

1. Historical: Applied to past events and activities recorded and observed over the catchment to establish an understanding of an area of study e.g. traditional indigenous culture, health and emergency services, infrastructure, mining and pastoral.
2. Comparative: Applied at micro level to historical research in the catchment to compare experience with present realities e.g. indigenous culture and settlement, land use, climate and economy.
3. Descriptive: Applied to situations when observing the community and environment of the

catchment and primarily gained to assess conditions and usage whilst the observer is travelling through it e.g. fire scars, four-wheel drive track erosion and mining pollution.

4. Correlational: Quantitative study of the relational study of climate change on the catchment and the prediction study, using mathematical modelling to predict the possible outcome of the nutritional status of pasture under future climate change scenarios.

5. Experimental: Applied to processing FNIRS and phosphorus testing.

6. Evaluation: Applied when investigating government policies and practices on land use and emergency services implementation.

7. Action: Applied to recognising and observing pest weed infestation, river bank erosion and waterway pollution.

8. Ethno-genic: Where catchment survey participants submitted their opinions and values in their own environment. The researcher simply observed and recorded the submissions

4.7.1 Population Sample and Roles of the Researcher

Primary participants (stakeholders (35) those with an interest in the outcome), were surveyed to collect their responses. They are identified as representatives of state and federal government agencies, academic/scientific researchers, key residents, primary producers, mining industry representatives, community service groups (e.g. CWA, SES), health services, non-government organisations (i.e. Red Cross, Wildlife Protection), cultural and heritage groups.

The total sample group (53) consisted of those above plus residents, tourists, workers and visitors. Of note many of the interviewees submitted responses to both sample group question sets. Locations persons were canvassed in were: Kowanyama, Koolatah, Coleman River, Dunbar, Kimba, Pinnacles, Palmerville, Maytown, Laura, Highbury, Gamboola, Drumduff, Chillagoe, Dimbula, Bellview, Karma Waters, Mt, Mulligan, Palmer River,

Mareeba, Tate River Crossing, Walsh River Crossing, Irvinebank, Julatten, Mt. Molloy, Cairns, Townsville. The objectives have been determined from identifying the following key factors:

1. Environmental Impacts of Climate Change
2. Economic Consequences of Climate Change
3. Cultural Aspects of Climate Change
4 Adaptive Capacity of the Catchment to Climate Change

4.7.2 Data Analysis and Procedure

Data collection was made by an ethics-approved questionnaire set, inviting submissions, formal and informal interviews of 83 responses (Appendix B). Personal observation and photography has been incorporated to support the discussion.

Physical geographical topics surveyed included ground and tree cover, pest weed infestation boundaries, flood plain and event inundation boundaries and water turbidity (Geoscience Australia, 2010). Human settlement patterns and activities have been gained from both remote sensing and census statistical analysis.

Because the phenomenon of climate change is a new experience for the population and environment of the region, the proposal was to apply the model of Institutional Analysis (Gibson et al., 2005). This is based on the Centre for the Study of Institutions, Population and Environmental Change (CIPEC, 2005) model, which is focused on the systematic study of people's collective behaviour in institutions. The model was useful in its ability to explain the adaptive behaviours of institutions and population as they adapt to this major political, social, historical and environmental event developing in the region

4.7.3 Verification Methods

Discussion was initially conducted directly and indirectly from fifteen primary producers in the catchment with a mix of positive, negative and accommodating responses (Appendix B). Following the study, presentations were then delivered to these primary producers to deliver results which were followed by individualised and specific DAFF field advice.

4.8 Limits and Boundaries of the Study

A community survey (Appendix C) was conducted and provided valuable insight into the opinions of the individuals. Candidates often displayed caution in providing their responses. Indigenous respondents felt constrained, as their culture supports a group consensus rather than an individual's spontaneous type of response. To this end only the responses of formal representatives of indigenous communities are reported on. Pring (2005) cites the work by Skertchly and Skertchly (2000, p. 61) who demonstrate the cognitive dissonance between the type of information sought in the questionnaire and the 'world view' held by indigenous culture. The concern derived from seeking a community response was their uncertainty surrounding their knowledge of how this could impact them personally. At the time of interview everyone was observed to have a differing understanding of the topic of the impacts of climate change. The practice and process of researching nutritional status of the pastures of the catchment will continue into future years as the technology is dispersed through the producers of the catchment.

4.9 Conclusions

This methodology set out to place reason and order to a wide range of concepts, research results, and evidence from the literature. Climate change is a cross discipline

phenomena and best researched by various methodologies. In this instance a distinctive methodology was employed to create results from the data. Confronted with qualitative and quantitative data and information it was necessary to select a theoretical philosophy to allow reason and logic to determine e.g. a climate change mitigation strategy or a measure to assess the impact of climate change on the catchment flora. All this computation was needed to be accomplished within the researchers' knowledge, skills and abilities and still be supported by the published literature on the topic. The mixed methods approach that Cresswell (2005, p. 1) advocates best considered the data mix and was modified to fit the data gained from the research. The results support the choice and application of this methodology to provide the rationale for findings and recommendations' set out in the following chapters. This challenging exercise in applying the methodology as set out above required skilful interaction with a diverse survey population who ranged from hostile and guarded to gregarious and supportive depending on their circumstances and interest. Producers supplying faecal samples were all women because they were the only ones able to get among the herd to collect fresh samples before dung beetle infestation could start. Their efforts were rewarded when their results and interpretations came through and they could manage the herd to improve its performance. Regardless, the researcher suffered considerable banter from the station men for requiring the women to undertake this unpleasant task. Another valuable learning experience came from residents who shared of their rich experiences, history and local knowledge of living in the catchment. Such varied field work experience reinforced in the researcher the selection and implementation of the methodology chosen for this study.

Chapter 5

Results

This chapter will report on the results of the community survey and observations

made on the sites visited. Information and insight are provided into some of the sectoral and community strategies by which adaptation is taking place in the catchment. The aim of the survey is to seek opinion and experience from the community so as to ascertain their capacity, preparedness and progress along their journey to adapt sustainably to climate change

5.1 Catchment Survey Results

This chapter reports on the project findings, the progress made, strategies designed and implemented, and recommendations to further progress the adaptive capacity of the community.

The 53 participants in the survey submitted 83 responses. They were selected from across the community and were engaged in a range of activities. Their initial selection was based on a perception that they could contribute to the study. For example, one group of 35 attended a future planning seminar of the MRWMG (2012). They were representative of landholders and stakeholders who displayed an active interest in, and a consciousness for, responsible management of the land in the catchment.

Their responsibilities were:

1. Conservation and national parks.
2. Intensive agriculture, producing a wide range of primary products.
3. Grazing enterprises
4. Indigenous landholding communities and groups.
5. Mining leaseholders.

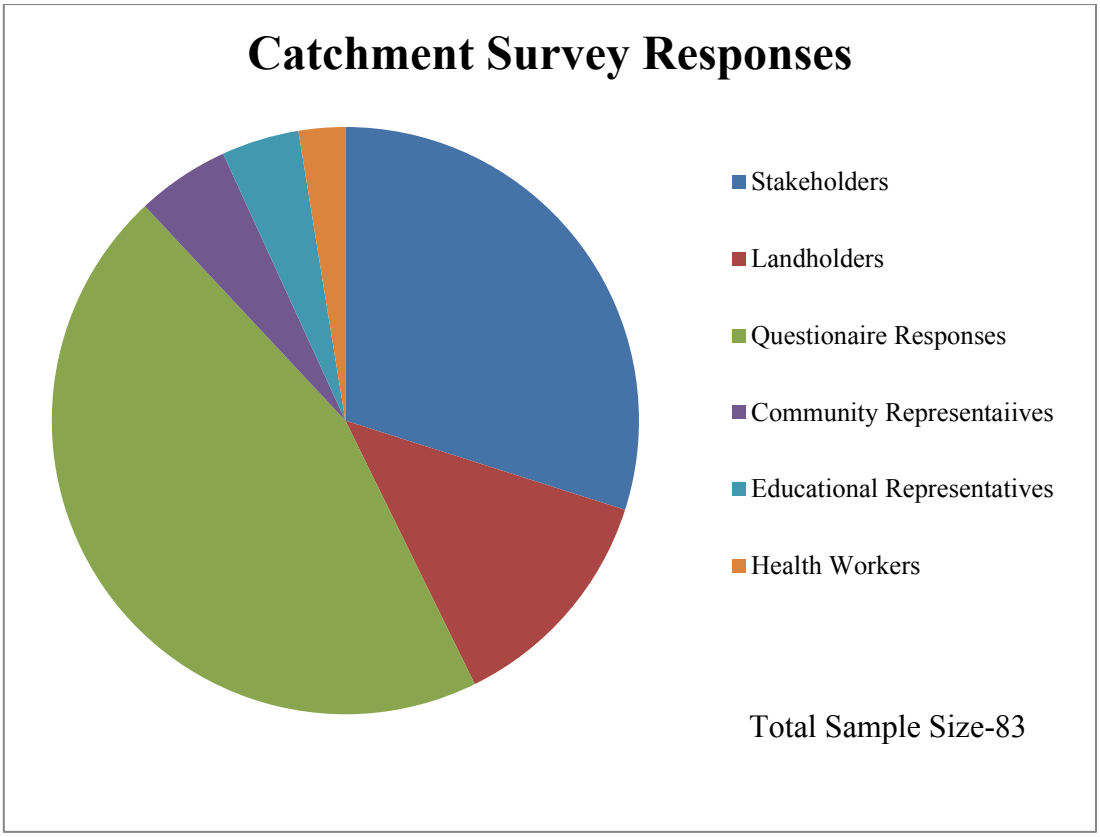


Figure 27 Catchment Survey Responses

Landholders displayed diverse philosophies and methodologies in their response to land management. In common with their awareness, they were all seen to share a joint responsibility to issues such as pest weed and animal management, fire control, erosion and public access. Many of these delegates were later to supply valuable data for the survey.

5.1.1 Visitors Questionnaire Results

Fifty-three people responded to the visitors' questionnaire from across the catchment (Figure 27, Appendix C); they were selected because they displayed an interest in and a willingness to contribute to the study. The responses are collated and listed for each question.

Table 6 Visitors Questionnaire Results

Question	Response	Explanation

Q. 1. Is this your first visit to the Mitchell River Region?	Yes = 17/53 No = 36/53	32% were first time visitors 68% were previous/regular visitors
Q. 2. What features attracted you to this region?		
	29/53 (55%)	(a) The catchment is at the start of the popular 'Cape York Experience'.
	48/53 (90%)	(b) Remote region with frontier style atmosphere.
	34/53 (64%)	(c) Good fishing.
	24/53 (45%)	(d) In transit to/from the Cape.
	32/53 (60%)	(e) Eco Tourism activities.
	25/53 (47%)	(f) Cultural/Historical e.g. relatives from the region, study of features of the region.
	47/53 (88%)	(g) Recreational e.g. 4WD enthusiasts, pig hunting, fishing, fossicking, metal detecting, bush walking/hiking, trail/quad-bike riding/tours, bush camping.
Q. 3. Positive experiences from visit to the catchment*	49/53 (92%)	(a) Good fishing/camping in reserved location in the estuary or upstream along river banks. (b) 'Glamping' experience at Wrotham Park Wilderness lodge (now closed). (c) Pig hunting/fishing, bush camping. (d) Challenging 4WD routes and activities. (e) Entertainment/sporting–Rodeo's races, wheelbarrow race etc. (f) Field days/industry/crafts /horticulture/ workshops. Cultural activities. (g) Wilderness camping.

		(h) Eco tourism activities, botanical/bird watching/endangered wildlife rehabilitation/bushwalking. (i) Improved access roads.
Q. 4. Negative experiences from visit to the catchment?*	29/53 (55%)	(a) Litter and human waste at camping/rest areas at river crossings (no refuse disposal facilities). (b) Illegal use of firearms at camps. (c) Poor camping etiquette. (d) Drunk drivers–dangerous driving. (e) Police 'harassment' of fishermen entering Kowanyama land and being searched for alcohol and prevented from camping along the road.
Q. 5. What facilities, infrastructure would improve your visitor satisfaction?	34/53 (64%)	(a) An organised catchment wide camping and visitor activities/facilities programme. (b) Improved supervision and maintenance of historical sites. (c) Track closures during wet season to minimise track and river access damage. (d) Provision and maintenance of bush camping sites.
Q. 6. How did you learn about the region?	51/53 (96%)	(a) From 4WD, camping, adventure literature, and websites etc., (b) Word of mouth, regular visitors or work related.
Q. 7. How will any climate change events affect your time spent and activities undertaken in the region?	5/53 (9.4%)	Climate change effects are unknown, it may moderate the southern winter and visitors may not need to travel so far north with higher ambient temperatures,

		which may decrease the time visitors stay in the area.
Q. 8. Your visit is important to the economy of the region. How have you contributed?	48/53 (90%)	(a) Camping/fishing fees at Kowanyama and station campsites. (b) Money spent at towns and tourist facilities and activities in the catchment. Reports of $100-$500 per vehicle was typical, examples are: accommodation, tours, food and drink, fuel, repairs and supplies.
Q. 9. What emergency procedures/preparations did you put in place prior to entry into the region?	35/53 (66%)	(a) Vehicle preparation and recovery equipment, (b) First aid kits. (c) GPS, satellite phone, UHF/SSB radio.
Q. 10. What facilities/equipment do you carry in case of an emergency?	37/53 (70%)	(a) Recovery equipment, winch, Snatch straps. (b) Extra spare tyres and fuel, water and food, medical supplies. (c) Solar panels and battery chargers, portable refrigeration. (d) Satellite dish for communications, UHF radio.
Q. 11. Has your interaction with the people of the region been a positive experience?	26/53 (68%)	Generally, there were positive responses of respondents interacting with residents and businesses. For example, many property owners permitted dog and gun free vehicles to transit with permission, providing the mustering of their stock was not in progress.
Q. 12. Do you plan to return?	32/53 (60%)	(a) Respondents reported they would favour an annual visit but recognised

	other limitations on their ability to travel the region. (b) Some said that they had ticked the box on their bucket list as they were in transit to/from the Cape and were not planning a return trip.

* Negative and positive experiences are compilations of multiple responses

5.1.2 Response from Property Owners Living in the Catchment (Figure 27)

Fifteen property owners were interviewed for this part of the survey of 53 to determine the issues most of concern for them. This is because catchment climate change mitigation depends primarily on land holders' knowledge, skills and abilities, Marshall (2010, p. 40). Significant issues that they identified were as follows:

1. All property owners had problems with unauthorised access to land. All had instances of theft, malicious damage, deliberately lit bushfires, illegal hunting, and litter. The hazard caused by negligent metal detecting is also an issue for some, where horses and quad bikes trip up in the holes created and injuries are reported to have resulted.

2. Property owners with children all complained of difficulties introducing the new Foundation to Year 10 National Curriculum in 2012, (Action Plan for Rural and Remote Education, 2011-2015) delivered through the school of the air. Over time this issue has been resolved through in-service training for the remote area educational facilitators. A comprehensive review away from the "academic style" format of the learning outcomes towards statements that was able to be comprehended by the learning facilitators. Eventually this has led to acceptance and implementation of the national curriculum (Queensland Department of Education and Training, 2015).

3. Freight, fuel, feed supplement costs combined with low cattle and produce prices were an issue affecting the viability of the business.

4. Agricultural producers in the MDWSS added to the above with additional issues with marketing their produce due to distance from markets and establishing a sustainable product base given the cost and availability of water. The condition of niche marketing proves so uncertain that confidence in forward planning is difficult if considering the lending requirements of bankers.

5. Damage resulting from pest weed and feral animal infestations proved an issue across the catchment for all.

5.1.3 Responses from Health Services Representatives

Because climate change impacts have already affected community health (IPCC 2014, p. 3) largely by aggravating existing health problems, a sustainable health service closely interconnected with the community is strategic. Climate change health adaptation strategies in the catchment are predicted to effect injury, disease and death due to more intense heat waves, bush fires, food and water borne disease (IPCC, 2014, p. 3. sect. 11.4–5).

The discussions with three health workers revealed their long-term, selfless commitment and caring attitude to the community members. For example, one well respected doctor has worked in the community for 13 years and has created social capital through strong ties to the community and forming wider community interaction with regional sporting and social groups. Patients from the clinic who require specialist treatment are flown (in all conditions) to Cairns Hospital by the efficient Royal Flying Doctor Service.

Facilities, although basic and dated, were adequate. Fatigue and isolation are issues, and being limited to two free flights per year, it is expensive to have a break from the community on the coast at other times. The six nurses work nine day shifts and as a result miss out on weekend breaks. Some agency nurses may not have the cultural sensitivity to patient care that can only come from living in the community. Some indigenous nurses may have to leave their posts to attend family business. Nurses reported the satisfaction and stimulation gained on the job, often against all odds. They enjoyed the variety of the work and the need to adapt to whatever problem confronted them in the isolated region. These skills should contribute towards a rural nurse recognition qualification should the award be made available.

Partners of health workers are often able to obtain employment in the community, which provides a financial incentive to stay and live in the community. The high cost of living required them to travel to the coast in the dry season and stock up on essentials to carry them through the isolation of the wet. A strong social network is maintained, and regular alcohol-free BBQ's and activity nights are held. The provided housing was of a lower standard and poorly maintained, so adaptation was required. Visiting health professionals from the coast expressed discomfort at being disconnected from their urban homes and living in basic motel style accommodation with limited menu options. The community does not have an ambulance and community, or private, vehicles are pressed into service when required.

The importance of effective remote area health services under the threat of climate change gains support from the IPCC (2014, p. 4) who determined that the adaptation measures most suitable are those providing essential health services including child health and vaccination.

Critical is also an increased capacity for disaster management and preparedness. However increased stress on the health system is coming from the alcohol, drug and gambling induced violence, the injuries of which require additional resources and time. One issue expressed was that the Kowanyama hospital is resourced to cater to a population of only 1,100. However, for various events the expatriate indigenous community will return and an increase to > 1,800 people is common and stretches the hospital's resources due to an increase in violence levels, especially during the wet when the risk from climate change health impacts have increased. This is because many of the expatriate community return for medical treatment as they are prioritised above those in the city and believe they get better treatment. An additional health issue identified in the community is a genetically derived delayed development syndrome in children.

In summary, significant issues are identified by this group as being:
1. Housing and maintenance needs to be maintained to a similar standard to that available in the coastal towns.
2. The retention of permanent staff through implementation of a remote area incentive package.

The above issues of community health services and infrastructure is important in assessing the vulnerability of health services to climate change impacts. The IPCC (2014, p. 37) advocate that improvements in public health services is the most important adaptation strategy to mitigate the health impacts of climate change.

5.1.4 Responses from Educational Informants (5 respondents)

Education is a key to mitigate social vulnerability, response and recovery to natural

hazard events Cutter and Finch (2008, p. 1). Future climate change disasters in Kowanyama may need a resilient educated population. The research investigated the remote educational facilities in Kowanyama.

Four teachers were interviewed, and all reported on the positive teaching experience with the younger children but were saddened when many of the older children moved with their peers into alcohol, drugs, crime and violence. The teachers found satisfaction in surviving the challenge of living and coping in the remote region and some had access to camping and fishing sites off limits to the public. They enjoyed the visits to various outstations with a clan and observed the traditional lifestyle living on bush tucker. They expressed concern for children affected by violence, poor living conditions and low school attendance rates. The teachers missed the active lifestyle that their life in the cities offered but were happy to 'do their country service' to be eligible to be transferred to a school of their choice on the coast. The Laura Dance Festival and similar cultural and sporting events were seen as a positive experience for the students and the children anticipated these events.

5.1.5 Response from the Community Informants (6 respondents)

Four clans reside in Kowanyama and this characteristic requires that a lot of discussion and debate occurs before any decision affecting the community is made. Climate change is recognised as an issue affecting the community and strategies to mitigate its affects are being discussed. These responses were sourced from community leaders who were able to submit a response representative of the community opinion.

An alcohol ban imposed by the community and enforced by the police had positive effects, although many people changed their spending to gambling. A leader suggested that a

generation may have to pass before the alcohol culture would be overcome. Unfortunately, the community has decided to rescind the alcohol ban and the community standard has regressed with the effects of alcohol abuse evident across the community. The IPCC (2014, p. 9) suggest that economic loss and poor health can affect indigenous communities under rapid climate change than that occurring in higher level socio economic communities.

The Work on Community program was withdrawn so the redundant workers reverted back to welfare payments and many community services and works were cut or abandoned. The community abattoir and butcher shop that killed local beef was closed as it failed to meet the governmental inspection standards. The cost to upgrade was prohibitive so beef must be trucked in during the dry season and flown in during the wet at high prices. The cattle destined to be a food source roam around the community unmanaged. However, the feral pig has become a staple of the diet, but this pest population is still at plague proportions creating damage to the environment, native plants and animals. Annual 1080 baiting programs are implemented to control numbers. Pest weeds affecting the community and requiring management action are rubber vine, chinese apple, sickle pod, para grass, hymenachne and grader grass.

The community has resolved to ban mining on land under their control. Sustainable fishing is the goal of the community and determines the permits available to tourists. No fish stocking program is in place but is being considered for the future. The major cultural festival for indigenous people of the cape is the Laura Dance Festival. Kowanyama has not previously participated but the community has decided to now participate in the event. The community has resolved to strive for and maintain a self-managed future and to maintain control over local government.

5.2 Public Access

Unauthorised and uncontrolled access to land is an issue for a climate change mitigation strategy. Harrison and Congdon (2002), and Bentrupperbäumer, Reser, et al. (2002) provide research evidence of the damage that the fire regime, pest weed and animal control, chemical and waste pollution has on the environment from unsupervised visitors to sites of natural attraction. The Wet Tropics Management Protection Policy (2014,) states:

> *Roads and traffic can have substantial harmful impacts on the Area by occupying and fragmenting wildlife habitat, contributing to erosion, sedimentation and pollution of land and stream habitats and facilitating the spread of weeds, diseases and feral animals* (p. 133).

The catchment survey for this study reported public access was a substantial issue for all the stakeholders (Figure 27). Landholders and some members of the public who were interviewed hold different, sometimes opposing, attitudes to the topic. The survey revealed a concern for some members of the wider community who view restrictions on land access as an imposition on recreational activities similar to that cited by Collins (2006, p. 8). This author suggests that many urban Australians hold to the myth that the outback is for frontier-style adventure (p. 1). Therefore, observation of this vast, unimproved, remote land such as the Mitchell catchment is used as an ideal location for a wide range of recreational and sporting activities such as camping, pig hunting, fishing, four-wheel driving, quad and motorcycle sport, mining and metal-detecting. This myth is perpetuated by the advertising and recreational vehicle and equipment industry that advertise and promote their products being used without boundaries or consideration in a pristine style environment.

The observations and interview responses from the survey for this research provides

evidence on the deleterious effects on many areas where public access is made available, such as road reserves and stock-route camping reserves. Pock marked, burned out areas of the Hodginson, Palmer and Walsh River mineral fields and other historical sites bear evidence of irresponsible metal detecting and prospecting where excavations are not backfilled.

All landholders related their negative experiences with unauthorised access to property. The resultant damage, erosion from vehicles, bushfires, litter, pollution and pest weed spread caused by visitors and their hunting dogs. They report that frequently hunting dogs become lost and breed into wild dog populations, attacking station dogs, native animals and cattle. Landholders related their negative experiences when, after remonstrating with trespassers, they frequently return to maliciously light fires, open or damage gates and/or shoot cattle.

Illegal fishers are known to set fine mesh nets across fresh water rivers or drag waterholes to catch species like barramundi, for which there is a ready market. Their actions are believed to destroy native fish species and introduce or spread pest aquatic plants and animals.

Indigenous communities of Kowanyama and (outside the catchment) the northern community of Pompuraaw who allow alcohol-free access to their lands on the Mitchell River for fishers. This is a valuable income generating venture for the community who provide basic facilities, rubbish removal and, importantly, limit the number of people accessing each camp. Fishers surveyed complained of high camping fees and limits on alcohol but tolerated restrictions with the incentive of access to prime and remote fishing grounds. The Kowanyama Land Office states that: *'Camping is restricted to four different locations: Topsy Creek, Wonya Creek, Bull Crossing and Shelfo'.* The community allows a

maximum of four camps at each location with each camp restricted to three vehicles per site. These controls are designed to provide a ‘remote and undisturbed’ camping experience. In addition, the pressure on the environment and, in particular, fish stocks is minimised, hopefully offering everyone a fair share. Minimal or no facilities are provided at each campsite due to annual flooding to maintain the wilderness attraction of the area. Fish species which attract sportsmen are: Barramundi, Blue Salmon, Black Jewfish, King Salmon, Mud Crab, Pikey Bream, Queen Fish and Spotted Grunter.

A fee is payable for all campsites, regardless of the number of people per vehicle. The camping fee is used to contribute to land management and improving the traditional owner′s homelands.

Plate 3 Fishing campsite on Topsy Creek (via Kowanyama). *(Source: R. Beasley)*

Illegal behaviour was observed when one group of tourists surveyed utilised GPS technology to travel cross country and avoid detection as they established a fishing camp on the Mitchell River. They believed it was unfair that they should have to pay to access what they consider public land. They also believed that they had the ‘right’ to carry and consume

alcohol and bring guns and hunting dogs onto the indigenous-owned land. Their method was to enter lands at night, establish discreet camps, fish and pig hunt, then leave undetected, also at night. Police at Kowanyama are reported in the survey to be vigilant of this activity and patrol roads and tracks outside indigenous lands to search for alcohol and move parked travellers on.

River banks in the upper catchment provide a resource for extreme four-wheel drive vehicle activity as drivers test their machines and recovery equipment on river banks and steep slopes. Drivers establish a trail and the group continue to circulate along the circuit until the track becomes so damaged as to make vehicle movement difficult. Wet season rain then erodes the site and the erosion damage is seen to form a network of gullies (Plates 4, 5 and 6).

Plate 4 Cradle Creek exit (original coach road on far left)
(Source: http://www.fc4magazine.com/old-coach-road-maytown.html 4WD Club, Laura Maytown Coach Road 16-18th March, 2012)

Plate 5 Wet season track damage
(Source: http://www.4x4playfnq.com/viewtopic.php?f=3&t=6717&start=250)

Plate 6 Wet season detour damage

(Source http://i850.photobucket.com/albums/ab67/GU03_foz/b3ed2674.jpg)

Wangaratta Four Wheel Drive Club describes their July 2012 traverse of the track in their September 2012 newsletter (p. 9). This report epitomises the rationale behind the imperative of people to traverse route such as this. They stated that it was on their *'Bucket List'* for many years to travel this way up to Cape York. Tourists covered in this survey reported a similar desire to travel this track, classified as 'hard' in the four-wheel drive categories of Australian tracks. They reported that the challenge tested their four-wheel driving skills, vehicle and trip preparation. Interestingly, most (seven of the nine persons canvassed on this track) agreed that that they would pay a moderate maintenance and camping fee to traverse and camp on the track.

A survey from traversing this road found evidence and numerous examples of significant damage and erosion resulting from destructive driving, usually by groups of enthusiasts. Personal observations from traversing this 110-year-old road for the last 20 years is that recent irresponsible driving is the most significant cause of erosion and damage. Occupants of one four-wheel drive vehicle surveyed on this track were on a recreational pig hunting trip with dogs and guns. Over a kilometre of track and bush either side of their camp was on fire to flush out pigs, kangaroos and brumbies to be shot for sport (Plate 7).

Plate 7 Arson on the Laura-Maytown Track (2011) (Source: R. Beasley)

Plate 8 Establishment of an erosion site. Cradle Creek exit (original coach road on far left) (Source: http://www.youtube.com/watch?feature=player_detailpage&v=hLamuRIcX_4#t=20s)

The historic Laura to Maytown bullock dray road carries damage created by irresponsible four-wheel drive vehicle behaviour. To reinforce the claim, a search of the website 'youtube.com' revealed some 12 videos that were posted by four-wheel drive operators recording their adventures as they traverse this scenic and historic route. Four videos were seen to display driving actions deliberately causing damage to the environment (Plates 8, 9). The goal of these four videos was to display the ability of the modified four-wheel drive vehicles and equipment to negotiate the damaged and eroded ground. One of the videos utilised a modified four-wheel drive vehicle painted and signed as representing a national four-wheel drive equipment supply and retail business. Videos displaying destructive behaviour in this historic site is then utilised by the aftermarket industry to promote their products and thereby condone irresponsible conduct in the bush. Deliberate driving through swampy ground with the intention of testing a vehicle's four-wheel drive ability and recovery equipment is also featured in the videos. Damage to vegetation is seen and the resultant establishment of the clay pan land form is evident in these areas.

Plate 9 Cradle Creek exit, creation of track damage
(Source: http://www.youtube.com/watch?v=kD_fDsEZr7E (5.05.2012))

Status (from the extreme four-wheel drive vehicle community) is seen to be given to those who conquer this and other Cape York tracks first after the wet season. This activity prevents clay soils drying and liquefaction rapidly creates a bog of soft ground denuded of

vegetation, which decay into bulldust holes and require bypasses to be cut into the bush to allow ordinary motorists to pass through (Plates 4, 5 and 6).

Letters of concern about this activity were sent to the Member of Cook and the Cook Shire, but no response was forthcoming (Appendix D and E). The survey identified frequent occurrences of drink driving on the more remote roads and erratic driving and behaviour which accompanies it. These motorists enjoyed the trip while consuming alcohol as they travelled. They believe they were safe from prosecution as police presence was not evident. Instances of near misses and vehicle damage were observed and made light of by some of the tourists and considered as part of the adventure. Under climate change impacts Turton (2005, p. 142) suggests that increase in tourism and recreation activities threaten the natural characteristics of a region. Here off-road vehicles create the most severe impact on the natural environment of all visitor activities. The Wet Tropics Management Authority has implemented comprehensive controls and management strategies to minimise damage from vehicles (p. 149).

5.3 The Pastoral Industry

The pastoral industry is the largest land user in the catchment and is generally responsible for the maintenance and condition of the environment. Its critical response to the effects of climate change is the reason the industry is subject to considerable research and study for this paper. The population of the catchment involved in the grazing industry is observed to be major contributors and participants in the generation and maintenance of social capital. They participate in a wide range of social and sporting activities over the year and provide practical and emotional support to those in need. Most of the grazing land is used for breeding and the live beef export trade is a valuable market for catchment

producers. Therefore, a mitigation strategy to assist producers to maintain production through climate change effects was chosen in this study.

Because most of the catchment is used for grazing on unimproved native pastures. The nature of cattle is that they will graze on a wide range of available grasses, forbs and shrubs to satisfy their nutritional and digestive requirements. This study presents a method of monitoring subtle changes in the biology of the area over time. This is achieved by an analysis of the cattle faeces which then provides information on the type, nature and value of the graze over their range. Information gathered from a series of sites across the catchment provides a picture of changes in vegetation over time. The objective of this research sought to answer the question as to whether FNIRS technology applied to the beef cattle herd of the Mitchell River catchment is a suitable, cost effective tool for identification and quantification of changes in the environment of the catchment due to climate change.

5.4 Catchment Infrastructure

Improvements to the infrastructure within the catchment are critical to the development of climate change mitigating strategies. The previous chapter gave evidence of capability that can be made available that may diminish climate change impact (NSDR, 2011, p. 16). Adaptive capacity depends on the effective and flexible use of resources and the learning from experience gained (Stokes & Howden, 2010, p. 155). Over the course of this study improvements were in evidence. Examples are upgrades to the road network, access to the National Broadband Network, community health, Queensland Ambulance Service coordinating, RFDS and Care-Flight and provision of NRM services. These reduce some of the disadvantages of remote and rural living and allow residents some services provided to urban residents. Educational opportunities, e.g. School of the Air and vocational

training is in real time and available online. Residents of the most remote areas can regularly drive to cities for supplies, business, shopping and social activities during the dry season. SES and Rural Fire Brigades have benefited from improved training and equipment supplies. The NAFI has improved its range of, and provision of, fire service information. Improvements in mobile phone coverage, including the use of social media for emergency services, provide enhanced mitigation of disaster. A new feature of the infrastructure of the catchment is the sugar mill at Arriga, west of Mareeba, the first new mill in Queensland in 73 years. Here, cane from the Atherton Tablelands and MDWSS is processed to the juice stage, which is then trucked to the South Johnstone Mill. Such enterprise is opening land to cane cropping and providing additional agricultural and employment opportunities for this economically depressed region. It is a display of confidence for this fledgling industry, with more irrigated land being put into production each year. A result of this innovation is a source of molasses for the livestock of the catchment.

The most visible adaptation strategy observed over the life of this survey is the combined efforts by Cook, Mareeba and Carpentaria Shires to upgrade road networks in the catchment from single lane, graded tracks to formed, aligned and capped roads. Plates 10 and 11 evidence the new road from Koolatah to Dixie Stations. These new and upgraded roads, in addition to the causeway (Plates 12 and 13) provide an alternative western route from the Gulf to Cape York for tourists, cattle road trains and freight, environmental maintenance, ease of access for emergencies and an effective fire break. The quarry pits excavated for the road store runoff water for stock and the prolific birdlife of the region.

Plate 10 Koolatah-Dixie Road (before)

Plate 11 New clay/gravel capped road (after). (Source: R. Beasley)

Safe dry season transit of the lower Mitchell River has been provided by the innovative climate change adaptation strategy in North Queensland designed and built track pad and Poly Gabion causeway (Plate 12) over the Mitchell River at Dunbar-Koolatah crossing. Conventional causeway design and construction is unable to withstand river bed change and the rigours and forces of wet season flood events and dry season flows. This low-cost structure based on principles formed in the Roman times is proving suitable for similar crossings across northern Australia and overseas (Donlan, 2012). This two-lane structure works with the floods and, being ballasted by the river sand, it is designed to withstand

flood damage and loading by road trains, which reduce the freight cost. Residents and tourists are now able to safely cross and travel to their destinations.

Plate 12 Poly Gabion causeway

Plate 13 Detail at Dunbar-Koolatah crossing (Source: R. Beasley)

A new rock-based causeway on the Palmer River at Maytown Crossing allows improved access, except at peak flood time. This increases the period miners, tourists and service providers can access the area and lowers the cost of living and working in the region. Importantly, the road network construction and maintenance works train and employ indigenous workers in a variety of roles. Primary producers in the catchment successfully contract for civil engineering projects as a supplement to their income and utilise their plant

and equipment. This mitigation strategy proves useful as they can open and clear road damage after the wet season before council assets can access the area.

5.5 Natural Resources and Climate Change

Adaptation in the catchment is evidenced by the creation and maintenance of wildlife and biodiversity refugia within Conservation Areas and National Parks that are substantial landholders. Australian Wildlife Conservancy (2014) is a private trust with holdings in biologically diverse and sensitive areas of Australia. One of its holdings is the Brooklyn Sanctuary (Figure 15), which has been established to allow protection of threatened native flora and fauna.

Originally a cattle station, it has been destocked and is being rehabilitated into a sanctuary for over 200 species of birdlife. This not-for-profit organisation utilises volunteer labour and gains funding from a sustainable eco-tourism business. Savanna and wetland research, education and conservation projects add to the activity of this conservancy. The response from property owners, tourist operators and visitors revealed the story of the ongoing community interest in, and support for, the maintenance of this facility. Unlike governmental national parks and conservation reserves, the Brooklyn Sanctuary is mostly free of external political and financial influence and actively contributes to, and is a critical component of, the eco-tourism economy and development of the region. It is seen to work cooperatively with the community in activities and developing links.

The Julatten, Mount Carbine and Mareeba triangle have emerged as a major bird-watching area observing and recording over 190 species at Mount Carbine, 300 at Mount Molloy and over 200 at Mareeba Wetland Reserve. Mt. Lewis, the source of the Mitchell River, supplies

water all year, harvested by the cloud forest on its upper slopes. McJannet et al. (2007) suggest that temperature rise from global warming is predicted to cause this cloud layer to gain altitude, thus causing a loss of valuable moisture to the high-altitude forest. They determined that between 4 and 30% of the monthly water input into the forest is harvested from the clouds of the wet tropics. In fact, the ~ 6500 mm/year runoff rate they determine to be a significant source for downstream water.

5.6 Mining and the Environment in the Region

Mining is a long-established industry in the catchment with activity levels of the industry determined by the prices and contracts available at any one time. A climate change mitigating strategy includes mining and is designed to diversify income streams for residents. Small scale operators are operating on the Palmer, Alice and Walsh River mining areas. The only large scale mine is the Baal Gammon Mine at Watsonville near Herberton. The Mungana Kangara Limited Mine working the Palmerville Fault at Chillagoe is presently in mothballs. Recreational and illegal fossickers operating outside defined fossicking areas are a source of concern for landholders and occasionally violence erupts after disputes.

While conducting this research, one murder was reported to have occurred (July 2012) due to a dispute between a miner and the landholder who was charged with the offence. Four residents interviewed support the landholder in this case, indicating the depth of belief and conviction in the community. Statements like: *'the victim was duly warned so what else can we do?'* only reinforce that the *'frontier-style'* culture is still *in situ* and this belief system still accepted.

During the '*build up*' to the wet season, when most small mining activity ceases and miners leave for towns or properties, illegal miners use the idle equipment and are reported to exploit reserves whilst owners are absent, leaving fuel supplies depleted and machinery damaged.

Of concern to resident landholders and environmentalists is environmental damage from abandoned mining activity (Plate 14), as well as proposed development (Bartareau et al., 1988. Harris et al., 2003). In 2011, the Tablelands Regional Council rejected an application to sand mine 60Ha of the upper Walsh River. Gaye Taylor from the Save the Walsh Action Group said:

> *This company wanted to mine 60 hectares out of the river which is sand and materials out of the river, clear all the trees and the paperbark trees and then they were going to mine 10 hectares of our property boundaries the environment, the wildlife, because that's a wildlife corridor ... so we're really relieved.*

Plate 14 Erosion on the Palmer River Mining Reserve (Source: R. Beasley)

Monto Minerals-owned Baal Gammon Polymetallic Project (Plate 15) is mining copper and silver with associated indium and tin over a working area of 1km^2. It occupies an area over 17 historical tin and base metals mines that have been worked over the last 70 years. In February 2012, heavy rainfall caused an overflow of a tailing dam, and contaminated water and sediment flowed into Jamie Creek, causing a fish kill downstream and rendering water unsafe for drinking. This site on Jamie Creek is currently occupied by the Department of Environment and Heritage Protection responsible for mining licenses under the *Environmental Protection Act* reported that, on eight occasions between February and April 2012, the water quality of Jamie Creek upstream and downstream was tested.

Plate 15 Jamie Creek and warning sign on upper Walsh River, Watsonville Queensland.
Inset: (above right) Abandoned mine emission on slope above Jamie Creek.
(lower right) Installation of runoff erosion control mat. (Source: R. Beasley)

The report found levels of contamination in Jamie Creek below the mine for arsenic,

cadmium, copper, manganese, nickel and lead, exceeded drinking water standards for humans by as much as 25 times (http://www.savethewalsh.org/).

As climate change develops over time with the expectation of more intense rainfall events similar to the February 2012 deluge, the question raised is how to engineer mine site runoff to prevent contamination from tailings dams. The response to September 2013 has been to mine the ore body, the source of contamination, and increase the size of the tailings dam. Runoff control matting has been laid to stabilise the site, reducing erosion. See inset Plate 15.

5.7 Community Response to Climate Change

The important element in the mitigation of climate change within the catchment is the landholders. With detailed knowledge of their properties and district and awareness of their environment, they can monitor and act rapidly through their networks to mitigate environmental changes (pest plants, feral animals etc). Importantly, this valuable work is already conducted with little or no expense to the wider community. Local and state governments may assist if the issues raised fall into their area of responsibility or expertise. Advice can then be applied to a problem of common interest such as pest plant and animal control.

Community response to adaption to climate change in the Mitchell River catchment has revealed that both the community-based and sectoral or external approach is interacting to progress the adaptive process. NGRMG (2015, p. 32). NGRMG, (2010, Table 15, p. 8). This research has determined that the community is becoming aware, and concerned with, climate change, albeit at a low level of importance because the phenomena is perceived to

be external to their sphere of influence and they will adapt as with other challenges that present over time. They have researched and implemented a range of mitigation strategies with the assistance and incentives of local, state and federal governments. Residents have implemented some of the policy guidelines and have enacted specific programs, usually unaware of their importance to climate change. NGRMG (2015, p. 32), NGRMG, (2010, Table 15, p. 8), CFI Factsheet, (2012, p. 1)

Examples of external (sectoral) factors driving adaptive change NALWR (2009. p. 5), in the catchment were identified in this study to be:

1. Graziers on notice concerning the federal government proposal to tax animal emissions.
2. Local government liable to tax refuse land-fill emissions CFI. (2012, p. 1)

The MRWMG, NGRMG, local and state government are observed to be active in initiating the following strategies, many of which have been implemented over time:

1. Grazing land biomass control, carbon sequestration and animal emission management.
2. Stream and river bank fencing and rehabilitation.
3. Mine site rehabilitation.
4. Soil moisture monitoring.
5. Fire management.
6. Pest weed and feral animal control management plan.
7. Water resources inventory and management plan.
8. Wild life conservancies and National Parks and biological reserves.
9. Climate monitoring and recording service.
10. Erosion control via track location, vehicle and animal control.
11. Public access control.
12. Fisheries management.

13. Improved school attendance.

Each of these strategies is suggested to develop adaptation to climate change on the catchment through development of social capital, economic development and environmental resilience.

5.8 Cultural Characteristics

> Climate change effects on the population of the catchment are certain:
> *While others argue their homes and country are flooding now some have already had to leave or plan to leave their ancestral homes to somewhere foreign* (Sinnamon & Frank, 2010).

Population and settlement patterns are concentrated in the north-west in the Kowanyama indigenous settlement and in the south east on the MDWSS irrigation area.

Comparing the population profiles of Figures 14 and 28, a notable feature is also the skew to the older population profile (45–55 yr.) in the Tableland statistical area when compared to Kowanyama, which has a peak of population in the 35 to 45 yr. category and a more rapid decline (Appendix B) in the 65 to 85 yr. group. The population profile of the Mitchell River catchment (Figure 13) is an aggregation of the smaller statistical areas within the catchment.

Characteristic differences are evident from the different profiles of males in the 20 to 34 yr. cohort (Figure 28). Females in the 20 to 24 yr. percentile have differences from 2.82% in the Tablelands to 5.02% for the Mitchell River catchment, the indigenous female population being a greater portion of this profile. Minchilba (Appendix B) has no males in the 20 to 24 year group, but 28.73% of the population in the 55 to 64 yr. group, while Chillagoe has no females in the 20 to 24 yr category. For the 65 to 75 yr. percentile, the Mitchell River

records 9.4% male and 13.79% female while Kowanyama display 2.87% male and 2.99% female, indicating a shorter life expectancy for indigenous persons. Climate change effect on the catchment demography is uncertain, but the continued outflow of young people to the coast and cities is predicted to continue (Hugo, 2012, p. 76). Inward migration will be of mature adults seeking business/lifestyle opportunities or 'temporary migration' (Hugo, 2012, p. 82). The workforce is predicted to increasingly tend to follow the drive/fly in/out pattern to be economically and logistically viable.

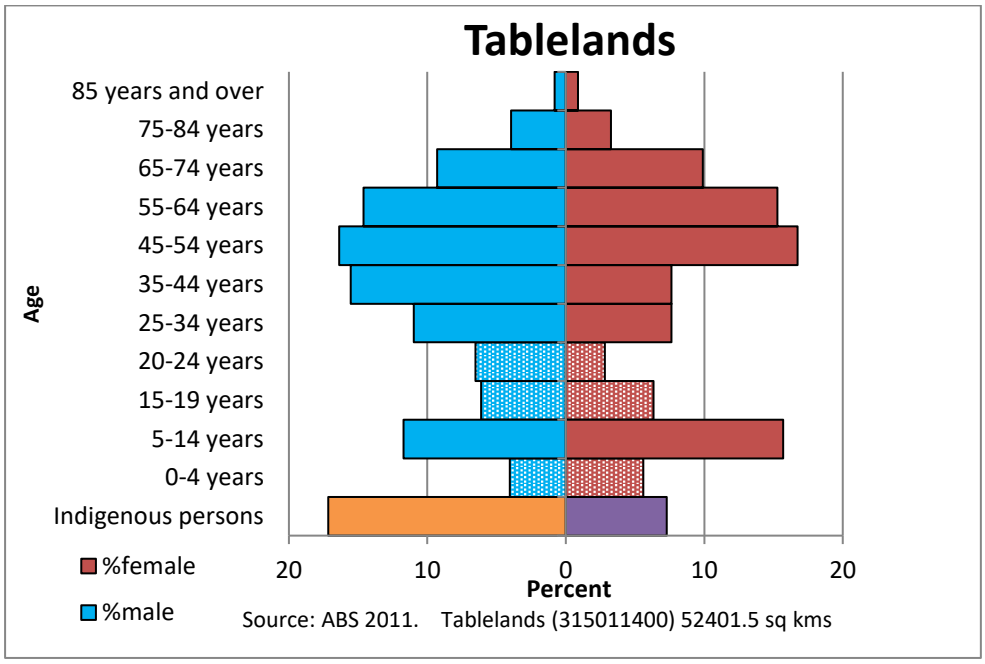


Figure 28 Tablelands population age distribution

5.9 Education

A priority of the Hyogo Framework for Action (ISDR, 2005, p. 6) was to: *'Use knowledge, innovation and education to build a culture of safety and resilience at all levels'*. The mitigation strategy of education is critical to the development of resilience across the community. Principles of 'life-long learning' became apparent within the community over the period of study and conformed to the experience of Cavaye (2004) and Faris (2004) in which persons develop meaning and purpose through learning new technology and thereby

creating resilience through increase in social capital.

The community survey results for this study (Figure 27, Appendix C) provided evidence of the population skillset and the desire and potential for community members to increase and formalise their skills and knowledge base. Thirty seven of fifty-three respondents from across the catchment reported to holding professional, tertiary or trade qualifications. When questioned if they would share their training/skills most agreed to the concept, conditions or commitments permitting. Some admitted having training that was not being fully utilised. Examples typical of this experience were a registered nurse performing parenting duties on a remote property, a trade qualified metal fabricator working on a property, a qualified teacher farming, and a diesel fitter managing a grazing property. Nineteen of this survey sample was observed to utilise skills and abilities for which they were not formally recognised. Taylor (31.03.2015) cited survey data from the NGRMG which revealed that 30% of property managers across the region only held yr. 10 level of education. He advocated an education innovation to upskill the workforce and to provide a career path to allow school leavers to remain in the region and contribute to the development of agribusiness.

The six teachers who were interviewed in the catchment (Figure 27, Appendix C) reported they felt a sense of achievement of having met the challenge to live and work in this remote location while accepting the difficulties. The observation of the researcher, (with 25 yrs. teaching experience) was that their commitment and affection for their students was seen to be much higher than their city-based peers. An observation was made at a gathering away from Kowanyama when 3 teachers, previously from Kowanyama were seen to actively seek out and identify past students to enquire of their progress and family welfare. Their positive

attitude is summarised in the seven-page information sheet titled: '*Things to know – Teachers newly appointed or transferred to Kowanyama State School'.* This document details the practical details required for a teacher relocating to the town:

> *Remember - Kowanyama is a very remote and isolated place, especially during the wet season. Your expectations need to reflect this reality. If you understand this, work around the challenges and maintain a flexible attitude, you will have an experience that will be enjoyable, rewarding and personally enriching, not to mention your professional growth into a classroom operator of the highest standards*.

Some teachers are unable to cope psychologically and have to resign or transfer to the coast, which is characteristic of remote communities. Parents and Citizen Groups in towns in the catchment were seen to prefer married teachers with children to boost the school enrolments and ensure the viability of the school. The provision of the ISBN across the remote properties of the catchment allow students to participate in live streaming of lessons from the school of the air and enjoy an improved educational experience. Parents supervising children in distance education reported problems with the recent change of curriculum but have since adapted.

Issues of concern for indigenous students were low school attendance due to absence for family business, domestic violence or moving to the outstations. The Kowanyama School and community have implemented an incentive strategy to increase retention and attendance. This has resulted in 90 students achieving 90% attendance in term 1, 2014. Families of students with 100% attendance receive a $50 energy card used for domestic electricity supply.

The COAG, NSDR (2011, p. 5) states *"Knowledge, innovation and education can enhance a culture of resilience at all levels of the community and should contribute to a continual cycle of learning".* A variety of education opportunities in the remote Mitchell catchment are considered necessary to generate social capital, resilience to climate change impacts and economic development across the community.

5.10 Personal and Community Health

The survey (Appendix C) identified community health to be an issue of concern for the indigenous community. The IPCC (2014, p. 6) notates the pathways by which climate change impacts human health, all of which relate to indigenous communities. The representatives of the Health Service expressed concern at the long-standing issues of isolation and fatigue from the six nurses at Kowanyama working nine day rotating shifts. In summary, significant issues health workers identified as necessities and deserving attention are:

1. Housing and maintenance to be maintained at a standard provided in the coastal towns.

2. The retention of permanent staff through implementation of a remote area incentive package.

3. Increase in the number of flight allowances necessary to allow nursing staff time for recreation away from the community.

4. Provision of a dedicated, equipped ambulance to assist patient transfers and in an emergency.

The Cape York Hospital and Health Service (HHS) Strategic Plan 2012–16 (which includes most of the catchment) declares their vulnerability in supplying health services. There is a

call for action in the catchment in their statement: *'the weaknesses for Cape York are those that result from size and location, and the issue of sustainable resourcing to allow the Hospital and Health Service to meet its challenges, retain and support staff, and plan and provide new services'.*

The threats are seen to be funding and health infrastructure. This is because Government funding priorities are often misaligned with the health needs of the population. Primary healthcare is not a priority for the current health system. The issue is maintaining health care infrastructure in the threat of: *'extreme environmental conditions, remote locations, unreliable power and supply chains, and high service costs'.*

The needs for the Cape York Hospital and Health Service services include:

> • *attracting and retaining health professionals, and developing Indigenous health workers;*
>
> • *increasing demand for services, and funding models that impact on the sustainability and financial viability of health care services;*
>
> • *suitability of health information systems to support primary health care and to evaluate health care effectiveness; and*
>
> • *increasing the health literacy of Cape York populations, and building personal and community capacity* (CYHHS, 2012)
>
> Support for this analysis of the CYHHS is formed from the IPCC (2014, p. 7*): " The negative effects of climate change on health may be reduced by improved health services, better disaster management, and poverty alleviation, although the cost and effort may be considerable."*

5.11 Economic Sustainability

Improved infrastructure for economic development is critical as an adaptation strategy in this region (NSDR, 2011, p. 14). Resilience is evidenced across the catchment across economic sectors. The live cattle ban in 2011 was followed by a distinct drop in beef prices resulting in a depression in this sector. The proposed China-Australia free agreement is expected to provide a significant future boost to catchment producers as they can effectively access the live beef export program (MLA, 2014). The improved road infrastructure will reduce the cost of trucking cattle to ports and permit a longer season transport to operate in the catchment.

Active mining at the Kangara mine at Chillagoe has ceased and the plant sold off. However, small mining companies are active, working reserves in the district which exploit favourable price and delivery contracts when available. The environmentally-damaging Baal Gammon Mine at Watsonville is operating at a reduced level, currently processing tin from local mines as a joint venture. Resources have been employed to control erosion and stormwater runoff. International demand for tungsten has reinvigorated activity on the Mount Carbine Minerals Province with Mount Carbine Tungsten Mine processing stockpiles and Vital Minerals are developing the Watershed Scheelite deposit with projected 49.2 million tonnes at 0.14% wolframite (WO3) with additional prospects on the lease, which is located 35 km north west of Mount Carbine (Vitalmetals, 2013). The most recent survey (conducted by this researcher for this survey, 2014) of mineral leases in the catchment indicated activity on many small mines in the catchment.

5.12 Tourism

Tourism maintains a critical role in the economy (Gurtner, 2007, p. 82) and is a factor contributing to the maintenance and development of social capital (Aldrich, 2010, p. 5). Preparation for adaptation is necessary to allow the industry to be sustainable in the future. In the catchment tourism long term adaptation will need to move from: '*autonomous and incremental to planned and transformational*' (Smith & Ash, 2011, p. 65). Brooklyn Station is an example of this transition over many years from autonomous to planned and incremental as wildlife populations declined due to land use changes. The economic value of the tourist industry of the sanctuary combined with the Julatten Mt Carbine and Mareeba triangle is significant and sustainable under the predicted climate of the next 30 years (CSIRO-BOM, 2014). The Palmer River Roadhouse is an example of an asset in the tourist economy of the catchment and has adapted to the business opportunity this location affords through the provision of accommodation and a historic photographic museum. It acts as a supply, refuel and accommodation hub for many tourists visiting the Palmer River Historical Reserve (Plates 16 and 17). This reserve is strategically placed in the diversified economic climate change mitigation plan for the catchment. Due to its place in the history of the North it is on the 'must do' list of many visitors to the Cape. Tourists are drawn to its remote and harsh location, its history and legends. A unique example of Australiana is located at the end of a dusty, difficult four-wheel drive track. It is the only structure in remote Maytown (Plates 16, 17) on the Palmer River historic reserve. This reconstructed miner's hut houses a visitor's book that recorded approximately 5,200 tourists between 12th June, 2011 and 7th August, 2013. Apart from independent tourists, evidence derived from these entries shows that commercial and tag-along type tours of all types have increased in popularity over the time. The frequency of overseas addresses also was seen to have increased over time. An important point of note is that vandalism and litter was not evident

at this popular, historic yet unsupervised destination. This valuable asset should maintain viability across future climate change scenarios because visitors can visit over an improved, resilient road and most modern vehicles are air conditioned. In this section tourism is considered a separate entity to the problem of unauthorised access and environmental damage as described earlier. The tourist activity observed for this research is noted that persons behave in a rational, sustainable manner quite unlike those who simply visit a nearby remote region to behave in an anti-social and/or criminal manner.

Plate 16 Reconstructed miner's hut. (Source: R. Beasley)

Plate 17 Stamping Battery Ruins, Maytown. (Source: R. Beasley)

Tourist industry at Chillagoe, Kowanyama and the nature and wildlife reserves surrounding Julatten and Mt Molloy tourism record satisfactory results over the past years with steadily increasing visitor numbers. Tourism operators in the eastern catchment continue to develop their resources with planning and strategies are underway to protect and support endangered wildlife from the effects of climate change. A range of innovations have been employed by tourism operators. One example is that of hosting international, school sized student groups who study history and environment. The historic Mount Tyrconnell Mine at Thornborough, grasping an opportunity, gain revenue from these regular groups who enjoy the unique experience engendered by the working battery and mine. The indigenous community at Kowanyama gains considerable revenue from managed, fishing campsites on the Mitchell estuaries. Graziers supplement their income providing campsites and facilities for tourists along river banks. Many are regular visitors and assist with tasks and mustering on the property using their own quad bikes and 4WD's.

5.13 Nutritional Information of Beef Cattle Project

The climate change indicator for the catchment is the collection of data on the nutritional characteristics of the beef cattle herd. The reporting on this data collection is the topic of this section. Faecal analysis then provides information on type, nature and value of the graze. From this information, two major outcomes are proposed. Firstly, graziers who closely monitor the environment on their properties will obtain ongoing benefit from this information and utilise the technology into the future to aid production. Secondly, researchers will have remote access to catchment-wide, statistically significant data on a range of environmental variables. The modest cost and considerable benefit from this ground-sourced information is suggested to be an added incentive of this strategy.

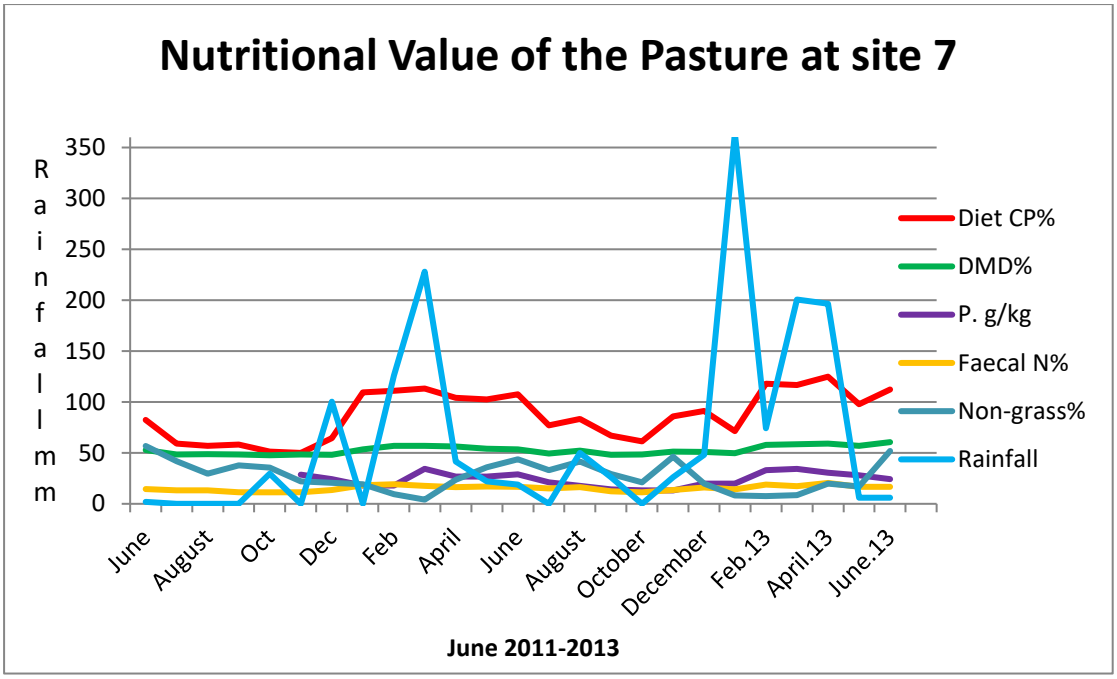


Figure 29 Nutritional value of pasture at Site 7, Eastern Highlands

Figure 29 is typical of the 27 sites surveyed over the period of this research. The red line (Diet CP%) demonstrates the critical variation in protein consumed by, and, available to the cattle. This protein is a function of plant nitrogen levels and digestible energy. Cattle grazing on a low protein diet lose condition (Craine et al., 2010). Timing feed supplementation in the June–November months would limit this loss of condition. A corresponding increase during this same period in the non-grass component of the diet (dark olive-green line) indicates the change in grazing selection to forbs and shrubs. Phosphorus is critical to bone growth and fertility. The Phosphorus (Purple) line indicates suitable levels from February to April. The remainder of the year the cattle are phosphorus deficient with deleterious effects on growth and condition. Supplementation will improve this condition. The aim is to collect baseline data (Figure 29) on the nutritional value of the savanna across the five biogeographic zones. This was achieved by six properties providing 27 data collection sites, which can be seen in Figure 30. Data collected from the FNIRS survey has been collated into four zones (Figure 32) and they reveal, for example, that catchment wide,

pasture protein levels have decreased only marginally through the dry season of 2012. This characteristic is significant, because, with advice to producers from DAFF extension officers on suitable supplementation formulations, stock at the 27 test sites were able to digest available browse and thereby maintain condition. This strategy is evidence of a mitigation strategy in operation and successful in achieving its goal in maintaining herd condition through digestion of a variety of browse. The mitigation strategy has provided a baseline data set and has also been demonstrated to primary producers and others as a future guide for catchment management. The rationale given for this research is that literature on the welfare of Far North Queensland under various climate change scenarios is inadequate and not directly relevant for the beef industry which is the commercial driver of the catchment. Consequently, a method of monitoring subtle changes over time is seen to be important and relevant to the primary producers. The larger portion of the Mitchell River catchment selected for this study is used for cattle grazing on unimproved native pastures, where they will by nature select from a wide range of grasses, forbs and plant material to satisfy their nutritional and digestive requirements.

Results obtained over 24 months from the 280 samples gathered from 27 collection points (Figure 30, Appendix G) display a range of results depending on location and pasture type. Over time, the database generated a nutritional profile spreadsheet for each of the sampled sites on the surveyed properties (Figure 29, Appendix G). Producers instructed and advised by DAFF extension officers have learned to apply this information to identify nutritional deficiencies and allow for appropriate supplementation and/or management strategies to be implemented. Skills acquired have been observed to be shared through social networks to other producers.

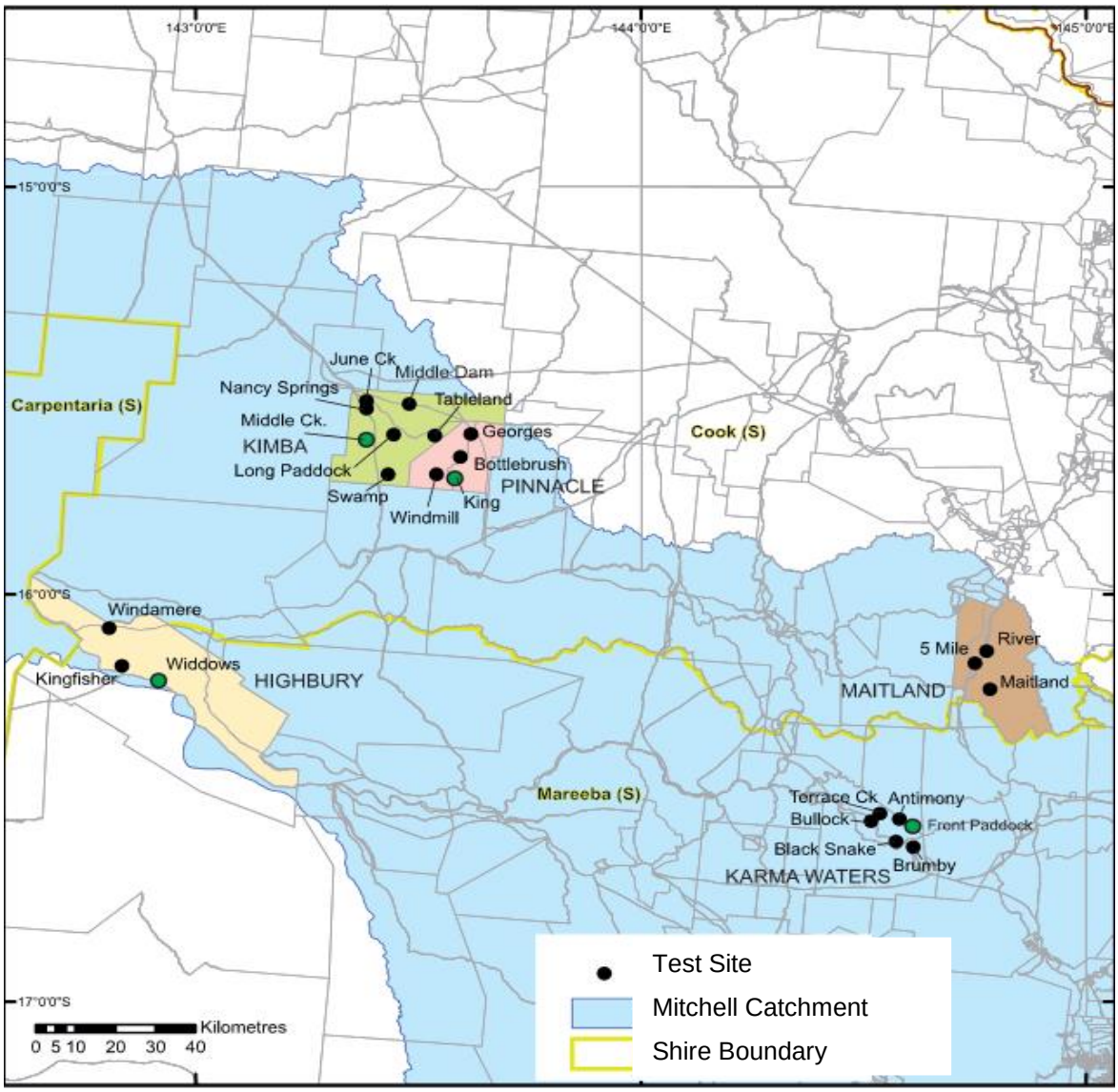


Figure 30 Pasture nutrition sample sites Note:-green sites indicate that samples were also sourced from nearby paddocks due to herd management needs.

(Cartography: A. Edwards)

To add a further dimension to this mitigation strategy, future climate change scenarios can be factored into the individual paddock spread sheet to provide guidance for future production and planning. A considerable benefit is that producers, when able to maximise breeding and beef production via a managed nutrition strategy, require a smaller herd size, thereby reducing the negative impact on the environment from grazing. This study did demonstrate the need for the FNIRS process coupled with willingness within the survey population to understand and apply the technology to their management decisions.

The FNIRS technology is based on north Australian research. This was undertaken to investigate the efficiencies and economy of scale that the industry gains from improved nutritional management. For tropical pastures, extensive and inclusive research has been conducted by Coates (2004) who describes the process of improving the reliability of FNIRS calibration equations. He applied FNIRS to analyse the diet quality of free-grazing cattle. The key element of this research was to determine the necessary calibration equations for the instrument. These, when applied to results of the FNIRS have proven reliable and accurate for predicting dietary crude protein (CP), digestibility, faecal nitrogen (N_2), dietary dry matter intake (DDMI), non-grass proportions and growth rate or average daily gain (ADG) of cattle grazing on tropical pastures. The caveat on the ADG value is that, as a single equation for growth rate, it was not able to be determined with confidence. However, on the Mitchell River catchment, due to similarities within pasture, valid growth rates may be realized. Problems to be addressed in the Mitchell River catchment are related to diets with high browse content and high non-leguminous forbs content. The faecal characteristics of nitrogen (N), phosphorus (P) and carbon (C) ratio are measured from the faeces sample and no special experiments are necessary. For a robust calibration equation though, the calibration set needs to be properly constructed and balanced to consider the variables in the diversity of samples. The researchers selected from thousands of samples those representing pasture type, diet quality and composition, geographical location, different seasons and over years. Carbon ratio (Δ C-13) values are composed of the naturally occurring Isotope C-12 and C-13. This critical reference value is used to determine the dietary non-grass component.

Coates and Dixon (2010) determined the nutrition value of tropical pastures across the seasons and the corresponding cattle growth rate. The outcome of this study was to

demonstrate the ability of FNIRS technology to estimate the diet grazing cattle selected. This proved the capacity of FNIRS to estimate the diet selected, change in live weight and the live weight response to a N_2 supplement. The breed of the heifers selected for the trial was *Bos indicus*, which fortunately is characteristic of the Mitchell River catchment herd.

5.14 Field Results

The results produced from the catchment led to the development of the database (Figure 31, Appendix G, results to date), a nutritional profile spreadsheet of each paddock on the properties surveyed has been established (Figure 31, 32). Producers are now able to identify any nutritional deficiencies and allow for appropriate supplementation and/or management strategies to be applied. Future climate change scenarios can be attached to the spread sheet to provide a guide for future production planning. Any decrease in Diet crude protein%, Faecal N% Metabolizable energy and Phosphorus can be moderated by supplement supply.

January 5.01,2	DNIT1441	FECN(e)	VIVO-MK3	DELF(e)	DELF(e)	ADG1441	FECASH10	DMD/CP	Phosphorus	Metabolizable		
	Diet CP%	Faecal N%	DMD%	Faec delta	Non-grass%	ADG g/day	Faec ash%	Ratio	g/kg	Mj/100kg LWT	P/N Ratio	
BB 214	7.43	1.47	50.17		8.24		23.58	6.75	3.76	11.19		Old Maitlanc
BB 215	7.13	1.41	49.62		8.31		15.58	6.96	1.97	9.47		5-Mile
BB 213	11.23	1.98	53.11		23.1		18.39	4.73	2.48	13.67		Maitland
BB 216	8.11	1.48	49.76		10.36		16.6	6.14	2.27	9.42		River
Feburary 5.02	DNIT1441	FECN(e)	VIVO-MK3	DELF(e)	DELF(e)	ADG1441	FECASH10	DMD/CP	Phosphorus	Metabolizable		
	Diet CP%	Faecal N%	DMD%	Faec delta	Non-grass%	ADG g/day	Faec ash%	Ratio	g/kg	Mj/100kg LWT	P/N Ratio	
BB221	11.06	1.81	57.07		4.16		26.01	5.16	4.94	17.85		Old Maitlanc
BB223	11.78	1.9	57.75		7.61		20.98	4.9	3.3	18.7		5-Mile
BB224	13.37	1.95	60.77		13.38		25.54	4.55	3.548	20.01		Maitland
BB220	13.59	2	59.46		13.87		22.42	4.37	3.13	19.33		River
March 10.03.2	DNIT1441	FECN(e)	VIVO-MK3	DELF(e)	DELF(e)	ADG1441	FECASH10	DMD/CP	Phosphorus	Metabolizable		
	Diet CP%	Faecal N%	DMD%	Faec delta	Non-grass%	ADG g/day	Faec ash%	Ratio	g/kg	Mj/100kg LWT	P/N Ratio	
BB 228	10.86	1.52	58.42		3.09		26.38	5.38	4.61	18.51		Old Maitlanc
BB 231	11.67	1.73	58.66		8.57		25.29	5.03	3.43	19.42		5 Mile
BB 229	11.49	1.86	58.69		18.44		22.28	5.11	3.71	18.67		Maitland
BB 230	13	1.87	60.42		7.6		20.43	4.65	3.43	19.58		River Flat

Figure 31 Nutritional Profile Spreadsheet Extract for Four Sites on One Property

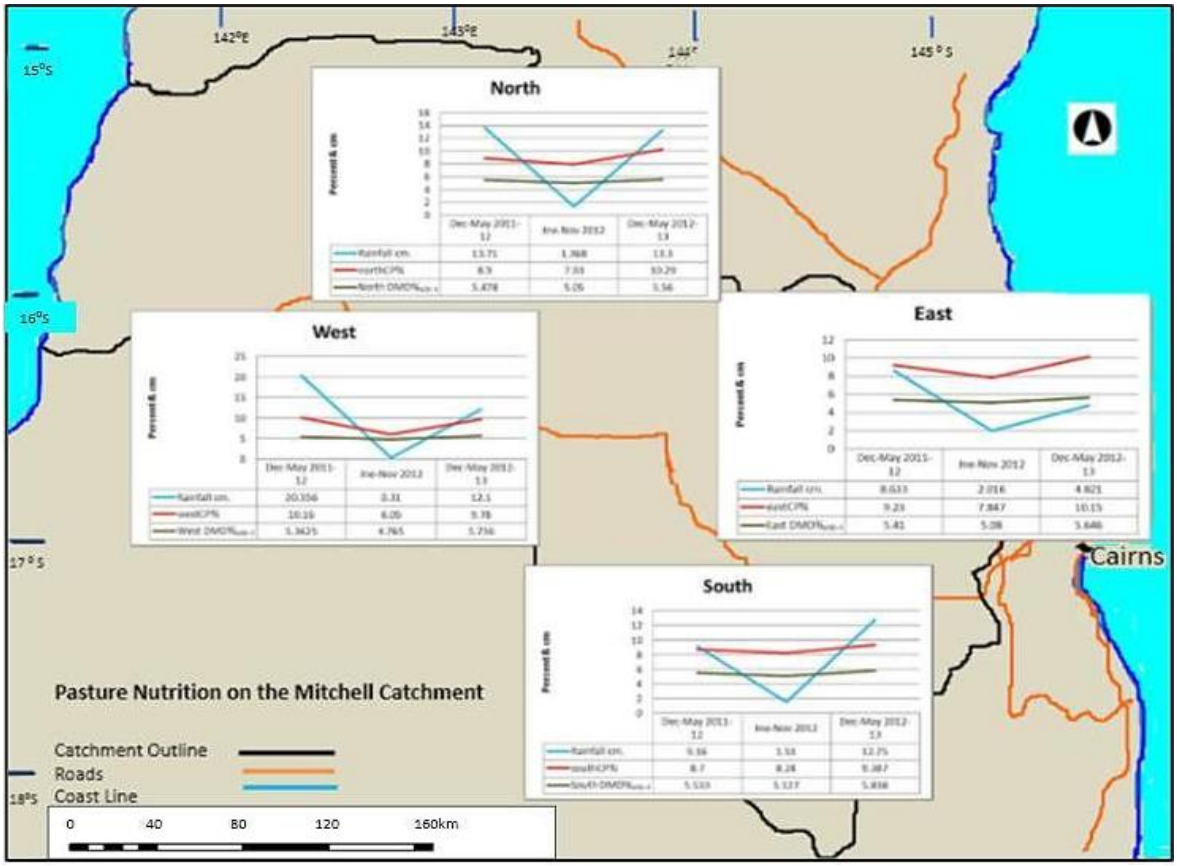


Figure 32 Nutritional values of pastures across the Mitchell River catchment.

Response from graziers confirmed the need for the process and the willingness within the survey population to understand and apply technology to their respective management decisions. DAFF animal scientists have collaborated by providing professional advice to graziers participating in the study to educate them in animal science and its application to their herd. This has resulted in surveyed respondents reporting that they are now able to more cost effectively, manage input costs and justify stocking rate decisions. Socially, they are better able to understand the production cycle and then relate their decisions to their peers.

5.14.1 Phosphorus

A critical indicator to the health, growth and development of the herd is that of pasture phosphorus (Figure 29, purple line, Appendix G). The effects of climate change may

significantly alter the inorganic supply of plant phosphorus. Dijkstra et al. (2012, p. 807) determined that under predicted climate change scenarios, phosphorus uptake by plants from soil and microbial activity in semi-arid grasslands may be constrained due to CO_2 increase, and a drying and warming climate.

Tropical pastures display low natural phosphorus levels in the pasture causing cows to present with low calving rates. The herd maintains a poor condition, and skeletal deformities like ‘bendy leg’. Cattle chew on bones to satisfy the need for phosphorus and risk botulism. Producers compensate for low dietary phosphorus by maintaining a larger breeding herd to maintain production levels and heavily grazing the riparian zone to source phosphorus rich plants. Critical timing of phosphorus supplement determines the cows’ response showing a marked increase in calving rate, thus requiring fewer breeders and reduced pressure on the environment to maintain production. Rolfe (DAFF, 2013, pers. comm.) has found from testing during phosphorus supplementation programs that marked improvements in the condition of herds in the catchment are proven. Unfortunately, during the October–January period when cows and new-borne calves require phosphorus rich graze to grow and thrive, the phosphorus levels in available graze are low. If producers can supply phosphorus supplement early, it can alleviate this distressing problem and increase calving rates and promote growth. This could cost $11–$21 per head for 3 month’s supply of phosphorus rich lick. Therefore, timing of this expensive process is critical to maximise efficiency and because dominant animals often prevent lower status animals from accessing the nutrient, even distribution across the herd is necessary. Climate change is expected to alter the supply of phosphorus that is available (Dijkstra et al., 2012, p. 808) from the pasture; therefore, the need for timely and accurate testing is required. To be effective in timing of this application, producers require a rapid response to the results of the phosphorus analysis. Experience

from this project has shown a 4-5 week turnaround between collection on site and the delivery of results. In practice this delay is way too long.

This study discovered variations in reported phosphorus test results (Figure 33 Appendix G). Due to an error in the order, the laboratory responsible for the nutrient testing also conducted the industry standard wet chemistry phosphorus test in their data run (red line). A control set of eleven of the results are displayed in Figure 33. The original laboratory forwarded their results (blue line) of the same sample. A significant discrepancy in the values became evident. This disparity was discussed with animal physiologists in Mareeba and bio-chemists at AIMS with a view to perform the sophisticated and laborious wet chemistry test to compare. The AIMS chemists suggested an ICP-OES (inductively coupled plasma atomic emission spectroscopy) total P test on the same samples (Figure 33, green line). In practice, in an hypothetical exercise, animal physiologists seeking to maintain phosphorus levels above 2.50 g/kg(DM) and using the red line of the data set would advocate supplement (at $21 max. per head) on 10 out of 11 of the sites costing up to $46,200 for a 200 head herd at each site. On information provided by the blue line, it would only be 8 out of 11 sites, costing $33,600. The green line would advocate supplement on 10 out of the 11 sites, which would also cost up to $46,200.

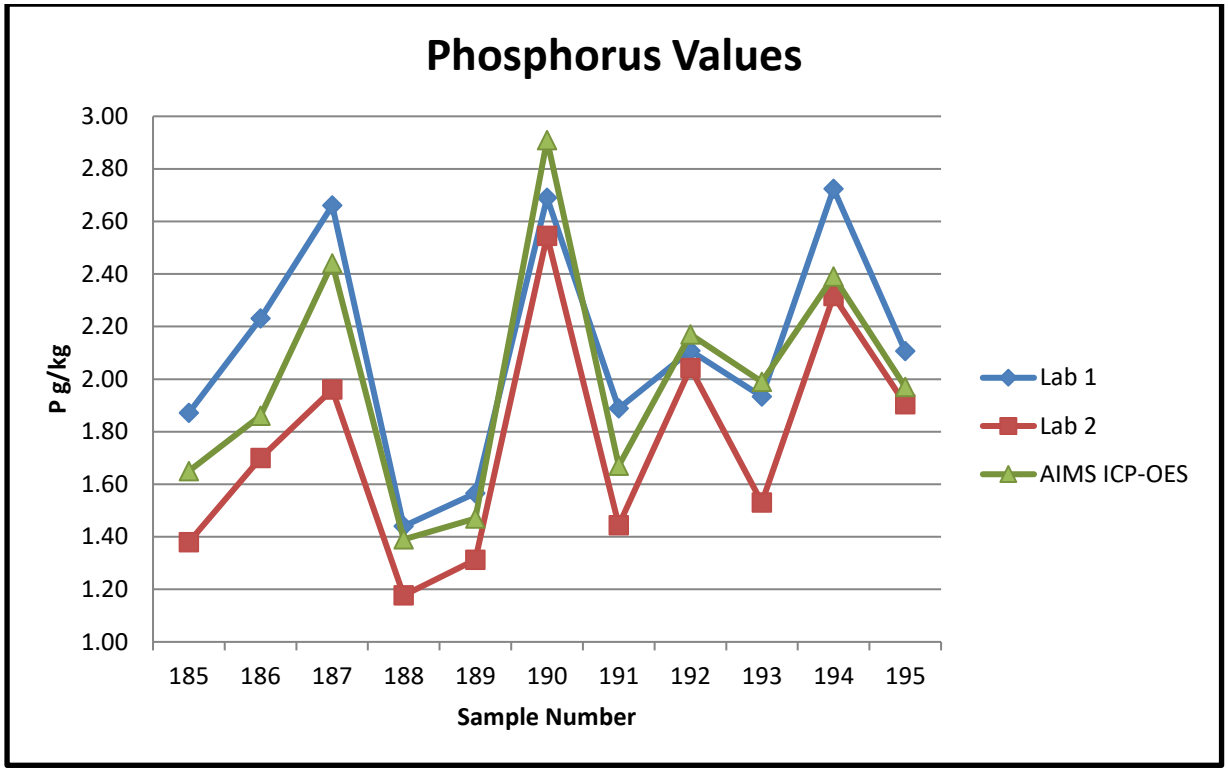


Figure 33 Recorded faecal Phosphorus values

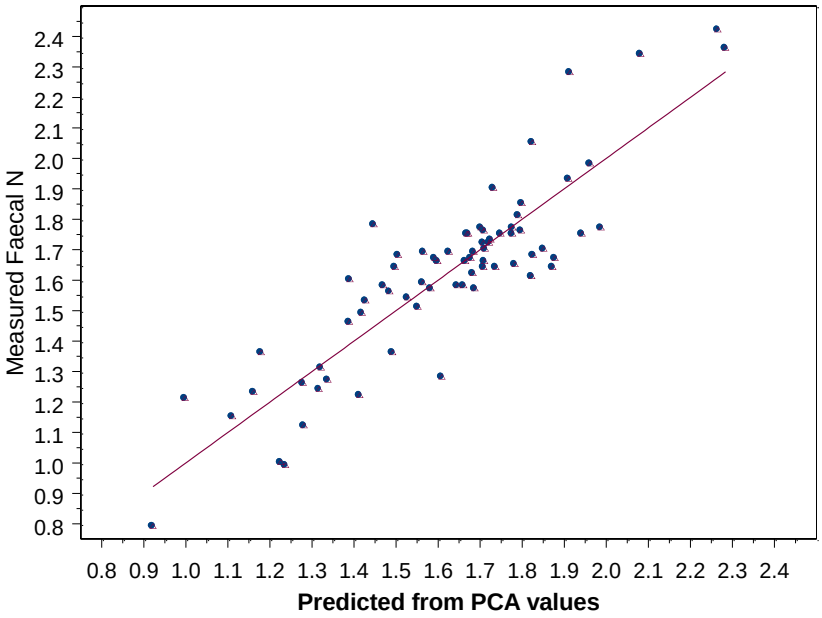
These samples obtained in October - November 2012 were selected from across the catchment, Maitland Downs, westward to Karma Waters and Pinnacle

The ICP-OES test can be conducted with a turnaround of seven days and is much more cost effective than the wet chemistry test and is conducted in north Queensland. Environmental benefits and a climate change mitigating strategy are that supplemented cattle can now thrive when fenced out of the riparian zone and maintain performance and weight of the herd combined with a lower stocking rate with the same production levels (Rolfe, 2013, pers. comm.).

Because future climate may not deliver the same results as evidenced in this baseline study, the variations will provide data useful for producers and researchers to plan and adapt to climate change. The extension to this concept was further developed with the research extended into the statistical analysis of the FNIRS data set (Figure 33, Appendix G,

Absorbance Data). Each sample was scanned over 1,853 frequencies in the near infra-red spectrum.

The results were analysed using Principal Components Analysis (PCA) techniques (Figure 33). This statistical analysis model was chosen because it should readily adapt to future data sets and provide predictions as pasture nutritional values change with future climate. The analysis produced a series of calibration equations, which enable predictions on the nutritional values of the cattle herd of the catchment. Two components; faecal nitrogen and crude protein (CP), are included to illustrate the predictions. The Y axis of the graphs represent the values as obtained from the testing laboratory. The X axis represents the correlation with the NIRS scan data conducted on the AIMS Perkin Elmer spectrometer. The predictions for Faecal N resulted in Multiple R^2 0.7832.SD = 0.1544, N = 72. Faecal CP returned Multiple R^2 0.8372, SD = 0.9923, N =72. This goodness of fit conforms to the industry value of 0.8 R^2 (NIRS Forage and Feed Testing Consortium, 2008, p. 7) and similar to equations developed by Coates (2000, p. 239) on a much larger sample size.



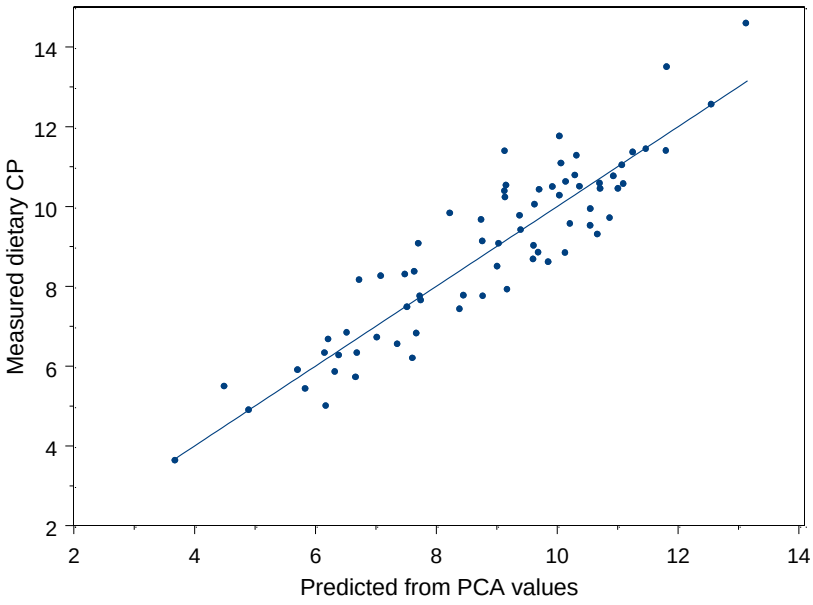


Figure 34 Predictions from Principal Components Analysis

(Statistician: R. Jones, JCU)

The results when presented to the respondents of the six properties participating in the study reported that with this information and training they are now able to more cost effectively manage the supplement input cost and are better able to quantify their production cycle.

They report that they are more able and confident to relate their management decisions to their peers in the industry. The result is the creation of a social benefit from this strategy. Beef production levels are maintained and the environment benefits from the reduction in stocking rates and a modified human-made fire regime. Initially the survey observed that pastoralists were critical of external climate change adaptation strategies for the catchment because of their confidence in local knowledge and the belief that they have the commitment, ability and resources to control many of the proposed effects of climate change. Results from the 2013 survey indicate this belief is no longer popular and producers have expressed more interest in the new strategies. A testimony to this strategy is the statement from the Karma Waters website, which was one of the sites where the pasture sampling was conducted:

> *Cattle on Karma Waters are Brahman Cross and we run a herd of around 1,500 mixed cattle. Supplementary feeding is done on a year-round basis and through the results of monthly dung tests for 2 1/2 years has identified the requirement to feed phosphorus for approximately 10 months of the year as protein levels are sufficient to allow for weight gains. The remaining two months the stock are feed 30% urea mix with 8-10% phosphorus to supplement lactating cows in the last part of the year* (http://www.karmawatersstation.com/cattle.html, 2015)

Improved and more accurate phosphorus testing technology is now available to producers, so the efficient utilisation of phosphorus supplement has proven to be cost effective for this producer.

5.15 Conclusions

The wide range of these findings created a need to combine them under the model of the research question (Section 1.3). Justification for this strategy is held by the Productivity Commission Inquiry Report (2012, p. 177) which found that it was not clear as to how planning systems should respond to climate change threats. However, the application of the 'precautionary principle' for proposed planning projects is justification for an uncertain future (Productivity Commission Inquiry Report, 2012, p. 93).

One application for an example of this strategy is the finding on Public Access to private land (Section 5.2). Research involved field observation of the damage caused, the potential hazards evident and the intense feelings of the landholders. Following a review of the published research on this topic determined the inclusion of the public access issue as a climate change adaptation strategy. The strategy of the Wet Tropics Management Authority has, and is proving effective in controlling access to areas under their control. A proposal is for government to allow similar controls on access to land across the catchment. The likelihood of environmental damage is minimised. Failure to adopt this strategy may result in damaging environmental impacts. A change in attitude by the prevailing culture is needed to enable acceptance of a policy of controlled access to public and private lands. Controls to minimise the damage public access causes would also benefit large areas outside the catchment if not nationwide. The existing cost to the community would seem miniscule when compared to the future cost of control and remediation (PCI, 2012, p. 97).

The pastoral industry is the key agency in managing the impacts that climate change may impose on the catchment. The people on the land are observant and vigilant to any changes occurring on their own and nearby lands. Pest weeds and animal infestations, bushfires and

similar disaster will elicit an immediate response usually managed by the land holder in the first instance and external help is sought when the disaster exceeds their capacity to respond. Any support that can be extended to these people to maintain viability and profitability is welcome. The response from this study was to provide the FNIRS nutritional data to the producers to assist their management strategies as well as obtain baseline data to measure changes over time.

Infrastructure across the catchment, so important in adapting to climate change was found to be improving and service delivery more efficient through communications networks. Road and bridge infrastructure is continuing to be improved and upgraded reducing transport costs.

Chapter 6

Discussion and Strategies

The previous chapter reported on the results gained from the catchment survey, their individual characteristics and the relevance of the findings. The information analysis determined which data fit the parameters required by the research. This chapter is a review of the findings and provides evidence from the survey, laboratory results and published literature to justify the addition of these findings, either as adaptation and mitigating strategies or as recommendations for adoption by stakeholders. The research question set out to determine whether the environment, population and economy of the catchment will respond sustainably to climate change, by either the community or sectoral approach. The rationale to respond to this question is provided below, as are sustainable climate change-adaptation strategies to prepare and adapt to the impact on the population, economy and environment of the catchment.

6.1 Human Adaptation to Climate Change in the Catchment

Residents are expected to respond and adapt to climate change in a manner dependant on their individual and group vulnerabilities (Paton, 2005, p. 4; Robinson, 2011). Preparedness for the residents is dependent on individual, cultural and group preparation and participation. Critical to effectiveness is a relevant knowledge base and equitable access to resources (Paton et al., 2010, p. 195). The population profile (Figure 13) divides the catchment community into indigenous and non-indigenous. Proposed climate change adaptation strategies for the catchment involve two separate responses. One is the Federal and State Disaster Management Response to adapt and evolve so as to incorporate the demands of the community and be resourced in part by various government agencies. The other is the indigenous community model proposed to incorporate traditional systems and

strategies determined and managed by the community (Monroe, 2008), and, if required, resourced by government. This proposed model requires information, resource and technology transfer as a two-way flow to determine the most appropriate response to the emergency. The rationale for this innovation is based on Skertchly and Skertchly (2000, Table 1; Nakashima, 2000, p. 432), who detailed the variation and dissonance between indigenous and modern philosophy when applied to interpreting and understanding the environment. The support for the indigenous model is also derived from observations made during the community survey (Appendix B), which revealed a competent and adaptable community council in Kowanyama capable of developing its own response to climate change events based on traditional knowledge and experience and the proven ability to utilise modern technology to manage their lands.

6.2 Health and Safety

Personal and community health and safety are critical to climate change mitigation strategy (IPCC, 2014, p. 2). Preparedness for disaster is enhanced by a healthy population (Haikerwal, 2011, p. 2), maintained by robust service providers. In the catchment, human health is expected to be affected by direct impacts from climate change i.e. heat, drought, bushfire and flood. Events from nature could be from water, human and/or animal transferred disease. Human activities could cause impacts from occupational, nutritional and mental stress sources. In the catchment, dengue fever is present, and rainfall and warming may drive malaria into the catchment (IPCC, 2014, p. 6, 14).

To manage the future health effects of climate change is presently the challenge faced by the health services in the catchment, particularly with maternal and child health and the chronic and acute health effects of the aged cohort of the population (Larson, 2006, p. 7).

The demographic characteristics (Figures 13 and 14, Appendix B) support the population's demand for health services to the young, growing indigenous communities. The older population of the catchment also place a higher demand on medical services (Cape York Hospital and Health Service, 2013). The impact on human health from temperature extremes (> 35 °C) is included in planning by Queensland government (Climate Q, 2009, p. 37). For the Gulf region, predictions are that by 2070 the number of extreme temperature days, with averages > 35 °C, will double from the present 102 days to 222 days per year (p. 47). In the eastern catchment, Climate Q predicts an eight-fold increase in extreme temperature days from 4 to 34 per year (p. 41). This evidence supports the need in the catchment to adapt to the health and safety impacts of climate change, initially by improving public health and services and then developing '*transitional*' cultural norms and values leading to sustainable resilience IPCC (2014, p. 26).

6.3 Community

Connected, organised, and resilient communities are proven to be better able to adapt to disaster (Chamlee-Wright & Storr, 2011, pp. 266–282; King, 2007, p. 44). The initial climate change mitigation strategy for a community is to implement programs that enhance and develop a cohesive and connected community. Established community development activities include the popular Laura races, Laura Indigenous Dance Festival, Mareeba rodeo, Normanton Beef and Barra Festival, Back to Mt Mulligan Memorial Days, Walkamin field days, Chillagoe Country Music Festival, Chillagoe Big Weekend rodeo and races, Mareeba to Chillagoe wheelbarrow race, Dimbulah Lions' Festival, NAIDOC Week, Tinaroo Barra Bash (and tilapia removal) at Tinaroo Dam, grazing and primary industry workshops, Mareeba Rotary field day, Kowanyama rodeo, Mareeba Multicultural Festival and Mount Carbine rodeo. In addition, Cape York communities come together for a range of sporting

events, which are largely held during the dry season when the roads are open. From rodeos to country horse races, football to fishing competitions, sport provides professional and social opportunities for people from the remote communities. It is suggested that continuing development of, and support for, these activities are critical for community development as a strategy for climate change adaptation both in creating social capital, community development and economic growth.

Nine of the fifteen primary producers surveyed on the catchment are aware that climate change is occurring, although they have not observed evidence of the event on their properties. However, a significant adaptation enabler in the catchment was unknowingly adopted by the producers in response to commercial demand. This was the adaptation to breeding temperature tolerant *Bos indicus* breeds. This change has been imposed externally by the market for the Asian live cattle trade and has resulted in higher prices and increased demand, which is an economic benefit for the producers. Climate change modelling from CSIRO – MLA (2012, p. 3) indicates that the existing grazing economy of the catchment is exposed to declining future returns and increased input costs.

The economy of the catchment is primarily based on welfare and grazing ABS Community Profile (2011, Kowanyama, Tablelands). The dominant, welfare-dependent, indigenous population in the catchment is identified to be vulnerable to the effects of climate change. This may be because of climate extremes, disease, invasive pest plants and animals or sea level rise, which has already affected their traditional way of life.

6.4 Education

Achievement by the population of nationally recognised education standards is identified as a key climate change adaptation enabler for the catchment. This finding resulted from the analysis of the survey data and a similar finding from Taylor (NGRMG, 2015). This is the need for educational reform across the catchment. One strategy is for the implementation of the educational program of Recognition of Prior Learning (Department of Education, Training and Employment RPL, 2013, Appendix F). This program will allow community members to attain statutory competency standards. This educational initiative is focused on utilising the existing knowledge and skills of the catchment population, and supplementing this with training delivered by internal and external trainers. The goal is to increase and formalise the population's preparedness, resilience, and social capital in order to respond to new opportunities and the impacts of climate change. This strategy utilises existing Department of Education, Training and Employment (2013) and federal Department of Education, Employment and Workplace Relations (2013) training programs and funding structures. This concept also utilised the established structure of emergency management, COAG (2010) which also incorporates the effects of climate change into emergency management. The proposal is the adoption of the Mitchell River catchment educational model (Figure 35). This is applied, not only to hazard management, but expands to include a range of educational, human services, health and commercial goals. One important and planned outcome of this initiative is an increased sense of community across the catchment (Paton, et.al, 2010, p. 194).

The nationally adopted COAG Policy (2010, p. i) is a:

> *...whole of nation resilience-based approach to disaster management, which recognises that a national, coordinated and cooperative effort is needed to enhance Australia's capacity to withstand and recover from emergencies and disasters.*

This policy initiative is planned to be a shared obligation by governments, emergency management, businesses, communities and the citizens. The goal is to develop a dynamic evolving process of behaviour change and untiring organisations (COAG, 2009, p. ii). Importantly, this initiative utilises the concept of product sustainability, which is based on the premise that *'sustainability begins with first events'.* These are the events that transpire during initial planning and operation stages of a behaviour change program.

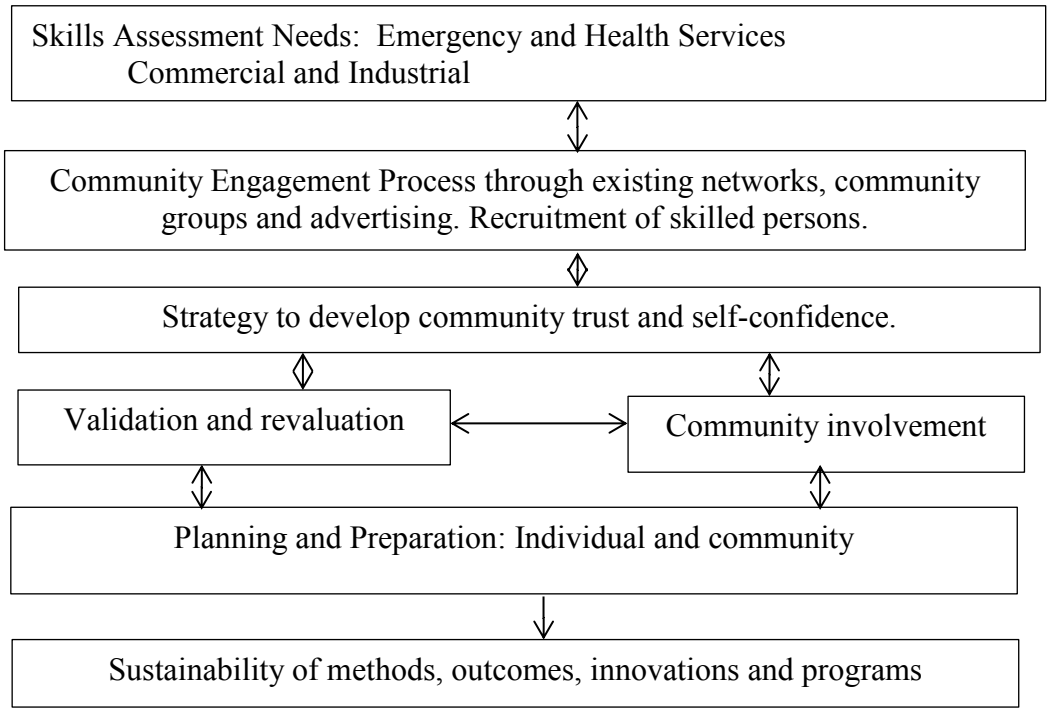


Figure 35 Mitchell River catchment educational model

(Source: EMA Manual 45, 2010, p. 6).

Because climate change is already affecting highly vulnerable Australian ecosystems, priority needs to be given to manage adaptive processes (Commonwealth of Australia, 2010, p. 12). Climate change impacts on plant diversity and distribution may reduce their resilience to invasive species and pests (Murphy et al., 2012, p. 65). Therefore, in the

catchment, the first responders (landholders) will need to have the necessary competencies required to operate the new adaptive management strategies (Murphy et al., 2012, p. 73).

6.5 Cultural

Sustainable climate change adaptation in the catchment needs to occur within the cultural contexts of the population. The catchment profile (Figures 13 and 14) displays the variation in age, ethnicity, socio-economic status and location. Climate change strategy implementation would be difficult if the strategy was not considered suitable by the public. This study seeks to investigate a theoretical framework by which a climate change strategy may be acceptable across the cultures. In an attempt to reconcile theoretical dichotomies of social systems such as agency/structure, subjective/objective and micro/macro perspectives, the principles based on the Theory of Structuration (Giddens 1984) and applied by Monagahn (2006) are selected. The method does not focus on the individual actor or societal totality: *'but social practices ordered across space and time'* (p. 2). Its proponents adopt this balanced position, attempting to treat influences of structure (inherently including culture) and agency equally. Simply put, the theory of structuration holds that all human action is performed within the context of a pre-existing social structure which is governed by a set of norms and/or laws which are distinct from those of other social structures:

> *Therefore, all human action is at least partly predetermined, based on varying contextual rules under which it occurs. However, structure and rules are not permanent and external, but sustained and modified by human action in a textbook example of reflexive feedback* (Giddens, 1984).

Structuration theory suggests that singular actions by individuals, family or community are affected by, and in turn affect, larger scale *'projects'* i.e. from intentions of local

groups to return to live in traditional homelands to regional planning proposals. One example of this process is a social and health issue arising from the survey that revealed in the Kowanyama community, following enforcement of alcohol restrictions, the vice of gambling developed into a major harmful element affecting community welfare. Gambling-induced crime resulted in theft, fraud, violence and family dysfunction. Children are reported to suffer from these negative effects and therefore urgent community action is required. Breen et al. (2013), following a wider study into the effects of gambling in indigenous communities, recommends:

> *The provision of indigenous counsellors, liaison workers and culturally appropriate gambling help services may play a critical role in reducing stress for those requiring gambling counselling. Recovery, rehabilitation and support are important components of a public health approach and should be available to all*
> From: The thesis remains unchanged.Indigenous Health in Australia, unacceptable differences remain. The Lancet (2013, p. 1158)

Another example of the structuration process in practice are the extensive programs conducted by the NGRMG, MRWMG and The Gulf Cattlemen's Association. One effective strategy they employ is the "On farm workshops" where producers supported by experts in the field demonstrate and share skills and knowledge on a farm-based topic. Producers then can learn about and adopt or reject the strategy for their business or lifestyle. Topics are as varied as remote sensing for soil moisture to managing physical and mental health. Here producers experience in a familiar environment the options available and have colleagues from their peer group share their experiences. This kind of interaction is described by Giddens (1984), as "reflexive feedback" where structure and rules are modified by the human actions producers experience.

6.6 Tourism

The climate change mitigating strategy that tourism provides has great potential to continue to develop under a coordinated and managed catchment wide, controlled access arrangement. Improvements in road infrastructure allow tourists to safely explore this remote region. Infrastructure and systems already in place in the eastern catchment to manage the Wet Tropics World Heritage Area (Turton, 2005, p. 140) need to be extended across the catchment. To protect the environment, this strategy is urgently required to control vehicle, dog and gun access as is the need for the supply of roadside facilities such as water, toilets and refuse points. Integrated with such strategies, existing public education programs effective in the wet tropics area of the eastern catchment need to be spread westward to inform tourists and residents of the required behaviour for a safe and sustainable stay in the catchment.

This research found that disused mining infrastructure and access roads have potential for further development into walking, 4WD, and mountain/quad bike routes. The Irvinebank tramway (1901–1941) has already developed into a popular quad/mountain bike route, while the Boonmoo–Stannary Hills section has potential to be developed further while still maintaining the heritage value of the area. Landholders and accommodation businesses in the area are earning income from this sunrise industry component.

6.7 Public Vehicular Access

An important strategy is proposed for the issue of public access to private lands. The evidence to support this strategy is based on the work of Brooks et al. (2009–2010) who in their studies on erosion of the Mitchell River catchment (Figure 17) concluded that off-road vehicle usage was a significant source of erosion and recommended limits on both usage

and site of vehicle access. Turton (2005, p. 142), studied impacts of public access in the Wet Tropics World Heritage Area of Far North Queensland, which is included and adjoins the Mitchell River catchment. Off-road vehicle usage was determined to produce the most harmful effect to the environment causing gully erosion, vegetation clearing, sedimentation and contamination of water quality with human sourced nutrients and pathogens and pest weed and animal spread. Holmes (2002, p. 378) suggests the public access issue on pastoral land is a consequence of the rural transition to 'amenity oriented' uses in which land use moves from pastoral to becoming, for example, an indigenous, tourism and mining resource. Collins (2006, pp. 1–10) researched public access issues on the environmental degradation vehicle-based tourism is causing through mismanaged recreational activities in the Kimberley region and submitted recommendations for controlled and managed public access.

6.8 Diversification of the Economy

The Queensland government's submission 'Agricultural Competiveness White Paper' (May, 2014) sets their commitment to double agricultural production by 2040. One opportunity is to include: '*Collaborative Research, Development and Extension, particularly in northern Australia to assist in facilitating development within the region*' (p. 1). Unfortunately, the potential of the Mitchell River catchment is recognised but it is given only a cursory role in the CSIRO approved Flinders Gilbert rivers development proposals (White Paper, 2014, p. 5). The high cost of agricultural water infrastructure is cited as justification. The creation of multiple uses of water supplies may support economic viability of development schemes (White Paper, 2014, p. 7)

Marginal farming areas are expected to be vulnerable to climate change (Stokes & Howden, 2011, p. 93). If the impacts stress the adaptive capacity of a region, the consequences, socially and economically are severe. For example, drought can severely affect the productivity of the MWDSS through the limitation of irrigation water. Feral pests and weeds expanding to fill a climate induced niche can only add to the financial burden landholders endure.

6.9 Environmental Adaptation Strategies

Integrated with the other climate change strategies being promoted in this chapter is the consideration for the environment. Howden et al. (2012, p. 42) suggest that environmental climate change mitigation strategies are critical: *'In essence it is just changing what we do to get what we want'.* Examples implemented for the catchment include modified fire management strategies to promote soil carbon sequestration and pest weed control. Feral animal control programs are being researched and promoted for the application of funding sources. Pigs, cats and tilapia feature predominantly in this category and require sophisticated and expensive methods of control (MRWMG, 2013). Gully erosion containment experiments are underway on Gamboola Station to study the effects of gullying on the catchment (Figure 17, Plates 18 and 19). River sand has been deposited at the head of the erosion to divert sheet water flow. New road design for the catchment includes culvert lining strategies to prevent erosion occurring from the beginning of construction.

Plate 18 Erosion at Gamboola Station

Plate 19 Gully erosion control experiment (Source: R. Beasley)

These, and a range of other factors, require the response of a climate change adaptation plan. Developed as a commitment to this project and to mitigate the predicted effects of climate change, this plan details the actions suggested for the population, industry and governments of the region. A holistic whole-of-catchment approach is required and is proposed to include:

1. Community consultation and involvement in managing and implementing adaptation followed by a community skills analysis. Design and implementation of training programs to equip residents with the knowledge and skills required to apply technology to local issues.

2. Co-ordinated whole of catchment pest plant and animal eradication and control.

3. Mine site rehabilitation and erosion control.

4. River and stream bank rehabilitation, revegetation and erosion control.

5. Road and track realignment and erosion control technology implementation.

6. Reduction in the stocking rate to match sustainable pasture production.

7. Sustainable and managed fire regime while maintaining soil moisture levels.

8. Controlled and managed public access to areas of natural significance and recreation.

9. Reintroduction of native birds, animals and plants into protected refugia distributed across the catchment to provide a resilient and adaptive population.

10. Roadside litter collection and toilet facilities at rest areas and recreation areas.

11. Control of domestic pets living in and transiting the catchment.

12. Increase in the number of climate monitoring and recording sites.

13. Adopt climate change mitigation strategy by applying FNIRS technology to the beef herd to provide the nutritional status of the pasture and floristic characteristics of the sample area.

14. Recognition of instances of best practice and innovation in adaptive management.

Pressland (2011, p. ii) advocates: *'Adaptive Management -The key ingredient is learning from doing, recording the outcomes and communicating them to those who need to know'.*

The environmental strategies generated by the project survey are:

(1) Control off road vehicle access to minimise erosion and control pest weed spread (Turton, 2005, p. 140).

(2) Erosion control from cattle by: (a) fencing off the riparian zone, and (b) reducing the stocking rate and increasing production through FNIRS determined supplementation (Dijkstra et al., 2012).

(3) Savanna rangeland adaptive management strategies to incorporate a range of diverse uses and users e.g. indigenous, farmers, graziers, miners and eco-tourists (Pressland, 2011, p. i). Integral for this strategy to be effective is for all people to adopt the indigenous, comprehensive, world view of environment as being '*integral and cherished* (Skertchly & Skertchly, 2000, Table 1).

(4) Active, coordinated, catchment and regional wide, control of aquatic and terrestrial pest animals and weeds within a fire managed strategy (NGRMG, 2015, MRWMG, 2014). One potential strategy is the free service provided by the Sporting Shooters Association (Farm Assist) who match qualified shooters to landholder's requests for pest control.

6.10 Infrastructure

The broad context of governance addresses the policies and resources allocated to control climate change adaptation activities and infrastructure (PCI, 2012, p. 78). Infrastructure is a national priority for adaptation action (Commonwealth of Australia, 2010). The capability of local government to influence climate change adaptation strategies requires adequate resourcing (p. 80). Transport infrastructure functioning under climate change is prioritised by Federal Government as critical to the economy. Government recognises the risk of climate change and the need for improved planning to mitigate risk (Philp & Taylor, 2011, p. 11).

Barriers to adaptation responses for infrastructure are considered by Philp & Taylor, (2011, p. 11) to be:

1. Misunderstanding the needs and responses required for climate change impacts.
2. Barriers created in red tape and miscommunication causing agencies to work in confusion that thereby prevent positive outcomes.

3. Lack of funding for adaptation measure implementation.

Critical to the agricultural development of the catchment is a reliable and cost-effective water supply. As discussed previously, CSIRO (2004) has discounted this option in the short term in favour of the Flinders – Gilbert project. The survey interviewed a long-time resident who has drilled extensively over the catchment for water. His experience was that good supplies were available from the aquifers for small-scale agricultural projects. The limits to growth are the cost of pumping infrastructure from water sources to the suitable soils for agriculture.

The project survey revealed the critical need for transport infrastructure improvements in the catchment; for example, the decision was made by Mackay Sugar to transport 700,000 tonnes of sugar cane from the Tablelands and the MDWSS to Mossman for crushing. A fleet of B-Double trucks pass through a portion of the catchment every 6 min, 24 hrs per day through the crushing season from April until December 2014 (ABC News 06.05. 2013). Damage to the road is evident and concerns are the road will be in poor condition prior to the impact of the wet season. As climate change increases temperatures, area under sugar cane in the catchment may increase subject to water availability thereby impacting the transport infrastructure of the catchment.

6.11 Grazing

A climate change mitigating strategy designed to develop the resilience of the beef producers in the catchment is but one application of the educational model (Figure 35). It applies FNIRS technology which is proven and tested on tropical pastures across the tropical north of Australia. It is a method of predicting the nutritional status and therefore

the performance of the herd. This strategy is necessary because one effect of climate change is the potential of a decrease in the nutritional level of the pasture and '*the availability of effective adaptation options* (Marshall et al., 2010, p. 153). The survey collected data and a nutritional profile of the catchment was compiled (Figures 29 and 32). Combined with the specialist knowledge and skill set of DAFF agricultural extension officers, tuition and advice on herd-condition was provided to graziers. The participants, having learnt and applied this technology to their business, were able to modify their supplementation program to optimise performance, efficiency, and lower supplement costs. The interest shown by participants was found to be shared by other graziers of the region and the application of this technology is being dispersed throughout the grazing community. This is similar to the technology transfer model described by Hayman et al (2007, p. 978).

The producers of the catchment are now able to test and have predictions analysed in North Queensland, thus providing critical information when needed for decision-making. This technology has economic ability to utilise the capacity of existing laboratory equipment and facilities. This innovation, though still needing further development across a greater data set, has created another climate change mitigating strategy for the catchment with further potential to be applied across the tropical north.

Innovations from this research developed outside the scope of the study and under development include the:

(1) Implementation of phosphorus testing utilising the AIMS ICP-OES.

(2) Development of calibration equations which allow producers or animal physiologists to determine the nutritional status of the herd either on-site or in a laboratory.

(3) Creation of employment and educational opportunities for persons conducting these tests on a professional basis across the catchment and the wider region.

Chapter 7

Conclusion and Recommendations

7.1 Introduction

Adaptation to anthropogenic climate change has emerged as an important research topic and researchers continue to add to the knowledge base. Considerable research and literature concerned with disaster management has been presented in this thesis. The focus of the study has been on a natural region of a large river catchment. The argument of the thesis is that all elements of society and environment contribute to adaptive capacity, and that these include supporting elements of the society and environment that are conventionally ignored by research into climate change adaptation.

The project survey has revealed that many of the impacts of climate change are, or can be, contained within the Mitchell River catchment. Pest weeds and fish, fire, erosion, mining and flood damage are examples confirmed from this observation. Therefore, the concept of focusing this study to within the confines of the Mitchell River catchment is unique and will hopefully seed further development of understanding of the geography of this and other catchments.

This project methodology set four research objectives in the introduction. These are presented here with the outcomes for each:

(a) Environmental impacts of climate change. The objective was resolved through the analysis of published and collected climate data with predictions from national and international metrological services. The environmental data relating to the catchment hydrology and the flora and fauna both inside reserves and across the catchment was reviewed and observed. The impact of pest plants and animals was observed and considered

in relation to predicted future climate scenarios and the existing limitations on resources and control expertise. Observation of the physical impacts on the catchment from sea level rise, salinity, mine site pollution, riparian zone gullying, grazing land degradation and the effects on the environment from the changed fire regime.

(b) Economic consequences of climate change were investigated as it is predicted to affect the agricultural, pastoral and tourist industries. The impact future climate will have on catchment infrastructure and disaster management services was reviewed and researched.

(c) Cultural aspects of climate change were investigated as future impacts could affect the sustainability of population and settlement through changes in economic, health, social and community services.

(d) Adaptive capacity of the catchment to climate change impacts was explored to observe the adaptive strategies and infrastructure and resources to mitigate risks and effects.

To resolve these objectives, it was necessary to complete seven projects that aimed to:

1. Determine the condition of the services residents had access to and identify needs that require attention. These were: Health and Welfare, Community Development and Sustainability, Education, Economy, Emergency Services, Rural Industry extension and development services, Catchment Infrastructure.

2. Identify and develop climate change mitigation strategies the community may choose to incorporate into their adaptation strategy. Primarily this is the strategy of Community Education based on the application of a program of Recognition of Prior Learning supplemented by education and training model to further equip residents to develop skills and knowledge aimed at retaining young adults remaining in the catchment (Figure 35).

3. Encourage residents to develop their own mitigation strategy for future application. The

adoption of the national emergency services training model is proposed to achieve this goal.

4. Identify vulnerabilities that may inhibit the development of resilience and assign priorities and/or strategies for their implementation. Perhaps the most important inhibitor of effective climate change strategy implementation is the need to control alcohol, drug, gambling and violence across the community.

5. Develop, modify or accept climate change mitigation strategies to be proposed to the community for their adoption. Preparedness was identified through these adaptation strategies already in place and functioning. These are:

a. Return of traditional lands and their management utilising customary methods.

b. Strategies to control alcohol, drug and gambling within the community.

c. Participation in regional cultural and sporting activities to improve traditional knowledge and understanding.

d. Active participation in catchment wide planning activities with groups such as MRWMG.

e. Pest weed and animal control and adaptation to using feral pigs as a food source.

f. Tourism innovation with a structured camping/fishing permit system.

g. Commitment from the local government to maintain a self-managed position.

6. Select a climate change indicator, practical in application and useful for the beef producers of the catchment as a mitigation strategy. This strategy was delivered through the implementation of FNIRS technology which allows producers to manage the supplementation regime to improve production from their herds.

7. Conduct a FNIRS baseline study of the grazing herd of the catchment. This base line study was completed, and the results collated in Appendix G and illustrated in Figure 32,

The research set out to investigate the possibility that residents of the Mitchell River catchment region may adopt a community-based response to the issue of climate change. The conclusion from this research is that they are adapting to climate change using this (internal) community-based approach. The sectoral (external) policy and practice is subtle and pervasive and mitigation strategies are modified to fit the characteristics and dynamics of the catchment. For example, the carbon sequestration trials have not reported the positive results found in other areas of the nation Rolfe (2013). Fire management strategies are reporting mixed results due to some landholders not conforming to a uniform policy. Arsonists are reported either to burn indiscriminately or in an to attempt to influence landholder's decisions. The trial mitigation strategy of balanced nutritional management of the beef cattle herd is displaying promising results, but the investigation revealed that some graziers were supplying supplement when the test results indicated it was not required. The rationale is because: *'the cattle liked it, and it made them compliant and easy to manage.*' They consider the cost of this supplement is justified to have manageable stock. Stock contentment was seen to take priority over cost. Nevertheless, producers utilising this technology now have the knowledge and ability to time the introduction of supplement and control their expenditure.

The major tourist attraction for the catchment is its remote location and visitors seek to experience the lifestyle this sense of remoteness engenders. Unfortunately, many land and business owners are not united or experienced in the management of this potential tourism resource. One instance is the increase in four-wheel drive adventurers on their way to Cape York to travel via the undeveloped western route. It offers a crossing of the magnificent lower Mitchell River and to observe abundant crocodiles in their natural habitat. This challenge is a major achievement for these tourists and a resource potential for tourism

operators. The new (polyurethane) bridge at the Dunbar-Koolatah crossing has endured four wet seasons and is operating and already well patronised by tourists travelling between Normanton and Musgrave. Potential is evident to develop into a major tourist route for the four-wheel drive and camper trailer population.

7.2 Research Question Discussion

This research project set out to explore the vulnerability to climate change of an area of North Queensland containing a unique and complex biodiversity. The issue investigated was:

(1) Will the environment, economy and communities sustainably adapt to climate change?

(2) Would they adopt either the community or sectoral approach?

The response is complex because each element will adapt in its own particular way. The environment will adapt naturally. With human intervention some undesirable impacts can be mitigated e.g. fire, pest weeds and animals, erosion and siltation. Management of the economy will focus on sustainable adaptation strategies, directed primarily to the pastoral, agricultural, mining and tourism industries. Community will adapt through development of social capital using strategies such as education and training, infrastructure development and health and welfare. The structures through which these strategies will be implemented are in place and simply need minor changes and suitable funding. One strategy identified as critical to successful adaptation is the retention, in the catchment, of young adults and families.

The second issue investigated revealed that the environment, economy and community of the catchment will adopt both the community and sectoral approach because both

approaches are necessary for adaptation to be effective. The community will adopt strategies after their outlook has been influenced by events and experience (awareness) Giddens (1984). The sectoral approach is critical for the preparation stage in order to have structures in place for when the community becomes aware of an issue and seeks to find a response. In the first instance, for example, water and feed placed in reserve for prolonged drought or planning and facilities in place for an invasive pest scenario or an uncontrolled bushfire. Another example is given when the sectoral approach to climate change is the only strategy to control vehicle access damage or pest weed or animal control. This is the only approach to provide catchment wide attention to an issue.

Completion of this project provided evidence of human capital and that the adaptation process conformed to a four-stage diffusion model described by Valente and Rogers (1995, pp. 242–273) as innovation, communication, time and social system. The stages and examples from this project were:

1. Innovation – individual primary producer process (awareness, trials and adoption of FNIRS climate change adaptation strategies).
2. Communication – the roles of information sources concerning the innovation were both formal and informal through personal instruction, interpersonal communication and formal interpretation by DAFF extension.
3. Model – the ‘S’ shaped rate of adoption with early resistance and eventually acceptance and adoption and saturation among the client group over time. The dispersion of the FNIRS technology within the pastoral community provided this example.
4. Classification of the technology adoptees – the observations were based on personal, social and economic characteristics (after Valente & Rogers, 1995).

Education was determined to be critical as a mitigation strategy. The catchment skillset will

more effectively mitigate climate change effects following training and development. The response to the question has been assisted through the creation of tools and recommendations designed to assist the adaptive process. Further issues are submitted for the community and governments to resolve and are discussed below in chapter 7.4.

7.3 Contribution to Knowledge

Concluding climate change opinion affecting the Mitchell River catchment from this project is that:

(1) The CSIRO Climate Adaptation Flagship (2012) and CSIRO-BOM, IPCC climate summaries and data (2012–2014) and their projections indicate the catchment should not suffer from the severe climate extremes and consequent disaster regime that is forecast for the temperate zones of Australia. This outlook could provide some assurance for people and industry in the catchment.

(2) This project determined that the infrastructure within the catchment is developing some resilience to the climate and the population has educational opportunities and access to facilities so as to advance personal development and generate necessary social capital.

(3) The introduction and acceptance by the beef industry of the FNIRS technology should provide: (a) a valid climate change indicator for researchers in the future; (b) valid rainfall data currently unavailable from official recordings distributed sparingly across the catchment; (c) producers with valuable information on the diet and health of the herd across the catchment; and (d) researchers with baseline botanical information on the selected graze of the herd across the catchment and monitor the changes in floristic diversity over time.

7.4 Future Research

Future research directions are identified as being:

1. Investigating niche crops and developing tropical fruit production supply when major coastal production areas are devastated by cyclonic activity or disease.
2. Requiring detailed education syllabus development to meet educational and training needs designed to encourage young people to live, study and train in this region.
3. Researching pest weed and animal control strategies, threatened and endangered species together with a system to provide and maintain refuges.
4. Developing incentives or penalties to address erosion, siltation and water pollution issues.
5. Improving climate modelling to provide accurate projections for producers in the area. This requires more weather recording stations and river and stream level gauges, particularly in the lower catchment.
6. Utilising traditional indigenous knowledge, as well as investigating and implementing sustainable climate change mitigation strategies, both within indigenous lands and across the wider catchment.
7. This research has discovered opportunities for employment for residents of the catchment and could attract commercial possibilities which, if developed with sensitivity to this environment and its peoples, would increase awareness of the uniqueness of this region.
8. The 280 collected faecal samples when subject to DNA survey will provide low cost botanical identification of the graze from identified sites and enable researchers continuing to collect samples to observe and measure future changes in the floristic diversity across the catchment.

7.5 Closing Statement

Reinforcing an optimistic outlook is the evidence from the literature and collected data that indicates confidence for the Mitchell River catchment both in the short and long term. The recent increase in demand for cattle for live export could help alleviate financial pressures on beef producers facing higher input costs. Agricultural producers face an optimistic increase in demand from a more prosperous Asia coupled with international free trade agreements in negotiation. Areas under sugar cane planting are increasing. The significant increase in tourism through the region and its varied attractions has the potential to distribute settlers and wealth for the commerce and community of the catchment.

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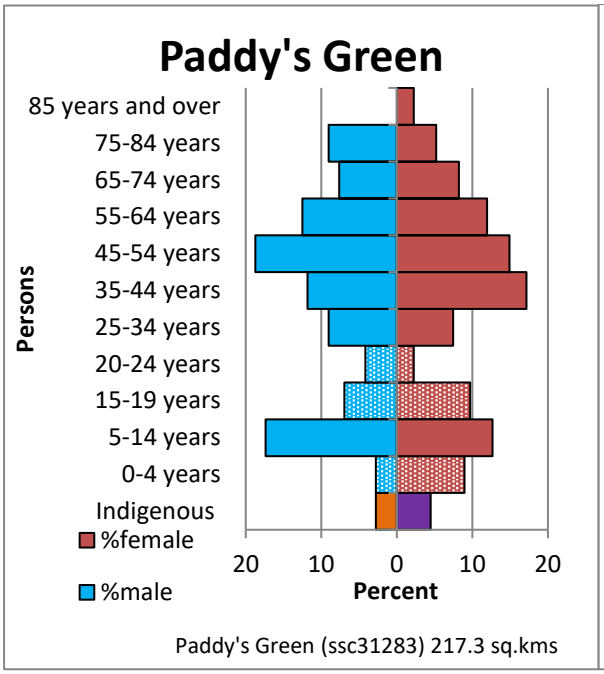
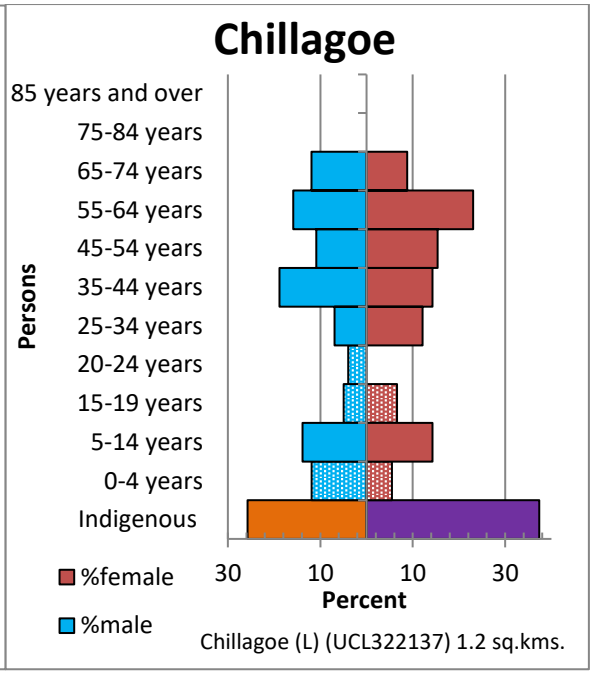
Appendices

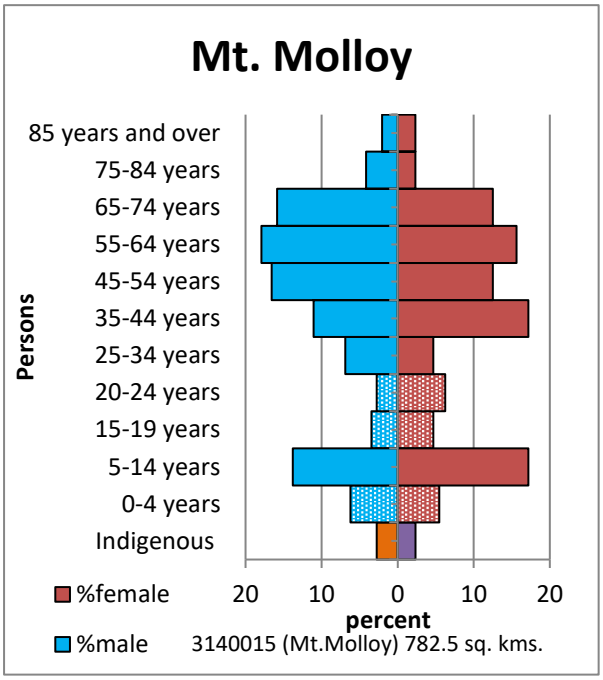
Appendix A

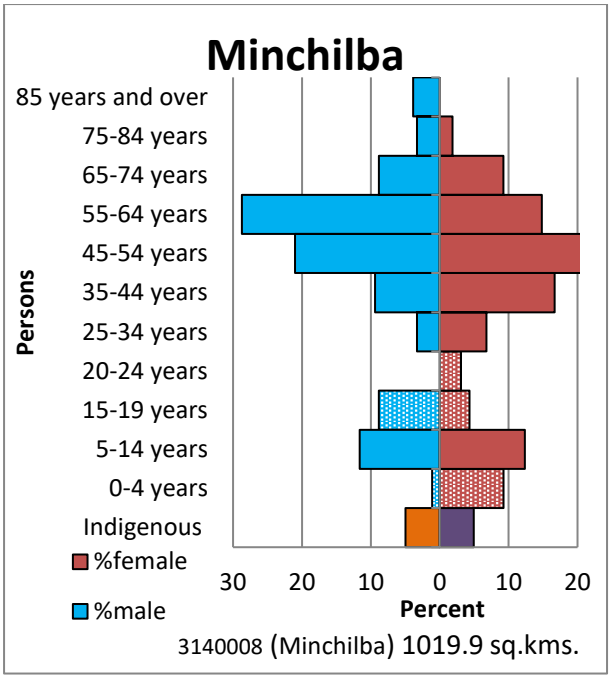
This administrative form has been removed

Appendix B

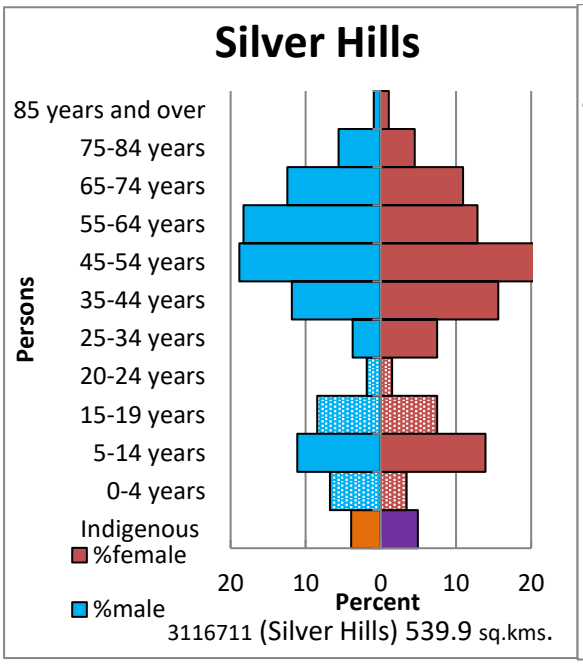

Paddy's Green
85 years and over
75-84 years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
20-24 years
15-19 years
5-14 years
0-4 years
Indigenous
Persons
%female
%male
20
10
0
10
20
Percent
Paddy's Green (ssc31283) 217.3 sq.kms


Chillagoe
85 years and over
75-84 years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
20-24 years
15-19 years
5-14 years
0-4 years
Indigenous
Persons
%female
%male
30
10
10
30
Percent
Chillagoe (L) (UCL322137) 1.2 sq.kms.

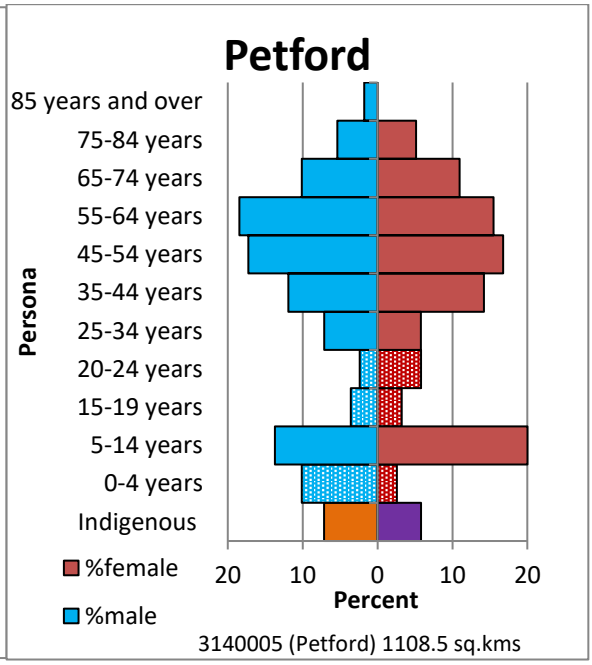

Mt. Molloy
85 years and over
75-84 years
65-74 years
55-64 years
45-54 years
35-44 years
25-34 years
20-24 years
15-19 years
5-14 years
0-4 years
Indigenous
Persons
%female
%male
20
10
0
10
20
percent
3140015 (Mt.Molloy) 782.5 sq. kms.



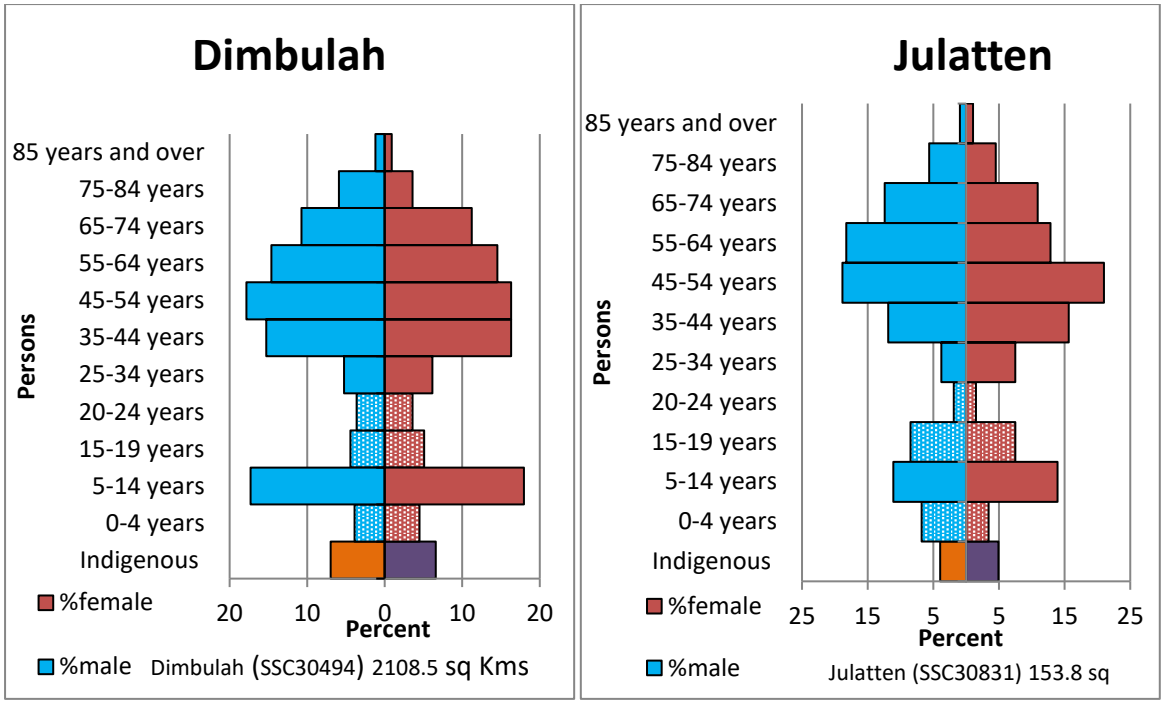
3140008 (Minchilba) 1019.9 sq.kms.



3116711 (Silver Hills) 539.9 sq.kms.



3140005 (Petford) 1108.5 sq.kms



Mitchell River Age Profile by Locality (8,470km^2)

(Source: ABS, 2013)

Appendix C

Visitors Questionnaire

This questionnaire is intended to gain a general impression of the characteristics of the economy community and living and working in the Mitchell River Region of North Queensland.

Your participation is entirely voluntary and your identity is confidential. You may withdraw at any time.

1. Is this your first visit to the Mitchell River Region?. Y N ……
2. What features attract you to this region?……
   ……
   ……
3. Describe your positive experiences……
   ……
4. Describe your negative experiences……..
   ……
5. What facilities, infrastructure would improve your visitor satisfaction?.....
   ……
   ……
6. How did you learn about the region?.....
7. How will any Climate Change events affect the visitors time/activities in the region?.....
   ……
8. Your visit is important to the economy of the region. How have you contributed?.....
   ……
9. What emergency procedures/preparations did you put in place prior to entry into the region?.....
   .....
10. What facilities/equipment do you carry in case of an emergency?.....
    ……
11. Has your interaction with the people of the region been a positive experience? Y/N....How?..
    ……
12. Do you plan to return? Y/N …..When?..... Bring other people? Y/N.....

THANK YOU FOR YOUR CO-OPERATION

Appendix D

Laura - Maytown Road
Robert Beasley
Sent:06 December 2012 09:10
To: mail@cook.qld.gov.au

Hello Cook Shire,
A recent visit to this area followed by a internet search has revealed that this area has emerged as a popular destination for the "Extreme 4wd" set who utilise this area to test their vehicles and skills in the most difficult terrain. The visible result is erosion to the slopes and creek banks. Creation of bogs and tree damage. One current trend is to traverse this region in the wet season due to the difficulty of the challenge. The track damage and extensive erosion is evident. Motorists proudly publish their activities and the damage created on the web. Attached are a sample of the 20+ sites a search revealed. A safety issue is suggested as ordinary 4wd motorists and motorcyclists are subject to a range of hazards created by damage to the track and environment.
Are there any measures the shire can initiate to protect this historic road and endangered environment for future generations?
Regards
Bob Beasley

http://www.youtube.com/watch?v=kD_fDsEZr7E
http://www.youtube.com/watch?feature=player_detailpage&v=hLamuRIcX_4#t=20s
http://i850.photobucket.com/albums/ab67/GU03_foz/b3ed2674.jpg
http://www.4x4playfnq.com/viewtopic.php?f=3&t=6717&start=250
Cradle Creek Exit; (Original Coach Road on Far Left)
Source: http://www.fc4magazine.com/old-coach-road-maytown.html

Appendix E

Laura-Maytown road
Robert Beasley
Sent:06 December 2012 09:13
To: Cook@parliament.qld.gov.au

Dear
My recent visit to this area followed by a internet search has revealed that this area has emerged as a popular destination for the "Extreme 4wd" set who utilise this area to test their vehicles and skills in the most difficult terrain. The visible result is erosion to the slopes and creek banks. Creation of bogs and tree damage. One current trend is to traverse this region in the wet season due to the difficulty of the challenge. The track damage and extensive erosion is evident. Motorists proudly publish their activities and the damage created on the web. Attached are a sample of the 20+ sites a search revealed. A safety issue is suggested as ordinary 4wd motorists and motorcyclists are subject to a range of hazards created by damage to the track and environment.
Are there any measures the State can initiate to protect this historic road and endangered environment for future generations?
Regards
Bob Beasley

http://www.youtube.com/watch?v=kD_fDsEZr7E
http://www.youtube.com/watch?feature=player_detailpage&v=hLamuRIcX_4#t=20s
http://i850.photobucket.com/albums/ab67/GU03_foz/b3ed2674.jpg
http://www.4x4playfnq.com/viewtopic.php?f=3&t=6717&start=250
Cradle Creek Exit; (Original Coach Road on Far Left)
Source: http://www.fc4magazine.com/old-coach-road-maytown.html

Appendix F

Department of Education, Training and Employment: Recognition of prior learning:

“Recognition of prior learning, also referred to as RPL, is the formal acknowledgement of a person's current skills and knowledge, no matter how, when or where the learning occurred.

This is an important assessment pathway, particularly for people who are considering doing some study. The recognition gained may considerably reduce the study time needed to get a qualification.

RPL is a process that should take place at the commencement of a person's training, apprenticeship or traineeship and it can take place throughout the training program.

The RPL assessment may include workplace observation, interviews and professional conversations, work samples and documented evidence.
Credit transfer

Credit transfer recognises previous formal learning (e.g. university, other qualifications). It uses an assessment of a previous course or subject that an applicant has achieved to determine whether it can be credited to the new course in which the applicant wishes to enrol.

The assessment determines the extent to which your previous course or subject is equivalent to the required learning outcomes of the desired qualification”.

Source: http://deta.qld.gov.au (2013)

Glossary

Definitions and concepts applied to this study are:

Adaptation: to gain a comprehension of the terms in usage in the relevant literature, and as a guide for this work, the NCCARF (2010) has prescribed the Australian definition for adaptation as: *'Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation'.*

Adaptive capacity: *'The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'* (NCCARF, 2010).

A community is: *'a social, religious, occupational or other group sharing common characteristics or interests and perceived or perceiving itself as distinct in some respect from the larger society within which it exists'* (Council of Australian Governments, 2011, p. 6).

Faecal Near Infrared Spectroscopy (FNIRS): developed for North Queensland pastures by CSIRO. It is a cost-effective and accurate method to determine the nutritional status of a cattle herd.

Precautionary Principle: The precautionary principle may be stated as supporting action even where there is considerable uncertainty. The general formulation in Australian law has the following 'intent: '*if there are threats of serious or irreversible environmental damage, the lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation'* (Peel, 2005).

Resilience: The widely accepted definition of resilience, originally derived from the ecological literature, is the capability of a system to experience shocks whilst retaining essentially the same function, structure, feedbacks and therefore identity (Walker et al., 2006). This so-called 'ecological' definition of resilience is relevant at various scales,

including biodiversity, ecosystems, landscapes, and integrated natural resource management systems. It can also be applied to social systems (NCCARF, 2010).

Risk management: A concept suitable to the address the hazard of climate change is submitted by Sellke and Renn (2010) who have introduced the concept of the umbrella term of '*risk governance*' to consolidate the activities of 'risk assessment', 'risk management', and 'risk communication' into one structure.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise). (NCCARF, 2010).

Sustainable development: '*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (https://www.iisd.org/sd/).

Tipping point: Russill and Nyssa (2009) reviewed the literature and applications for this term introduced from the social sciences and an epidemiological imperative to communicate the gravity of a change event. They cite Lenton et al. (2008) who view tipping points as 'a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system', and Moser and Dilling (2007, p. 492) definition: 'moments in time where a normally stable or only gradually changing phenomena suddenly takes a radical turn'. In their conclusion Russill and Nyssa (2009) conclude that: 'There is a greater need to acknowledge the metaphorical character of tipping point warnings of climate change danger, as scientists and others strive to reshape climate change as a social policy problem'.

Transformation: 'Where change exceeds the adaptive capacity of a system, it may be appropriate to reduce the resilience of that system to facilitate transformation, for example of species composition and even ecological function. Transformation at one scale (e.g. change of species composition and even ecological function locally) may be necessary to enhance resilience at a broader scale (e.g. persistence of those species somewhere in Australia' (Barlow, Grace, et al., 2010, p. 40)

Vulnerability: The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (NCCARF, 2010).