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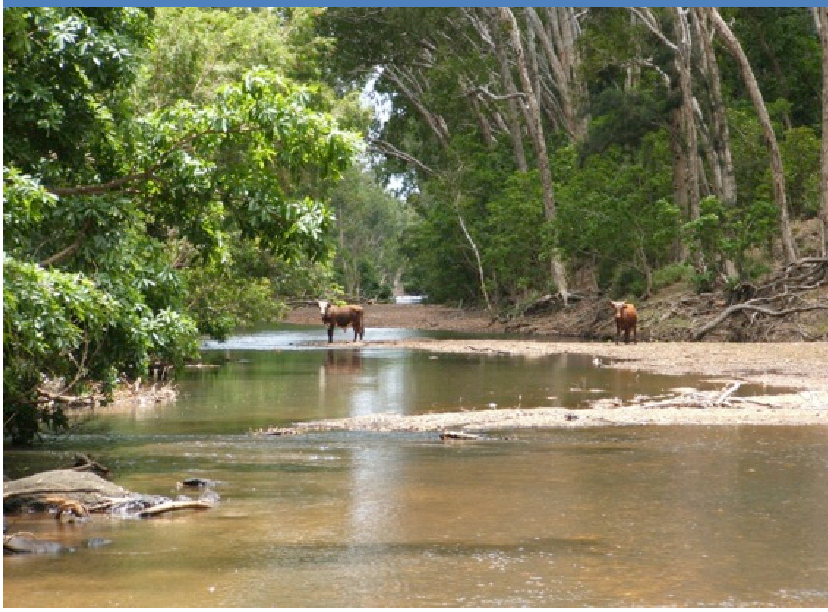
# Normanby Catchment Water Quality Management Plan

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CARING FOR OUR COUNTRY

Australian Government
Department of the Environment, Water, Heritage and the Arts
Department of Agriculture, Fisheries and Forestry

Reef Rescue Research & Development

CAPE YORK WATER QUALITY

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Other reports that have been utilized in the development of this plan include:

- Laura-Normanby Catchment Management Strategy (Howley & Stephan 2005)
- Laura-Normanby Water Quality Monitoring Report, CYMAG 2006-2010 (Howley 2010)
- Sediment Sources, Sinks and Drivers in the Normanby Catchment, Cape York Final Report - September 2012. (Brooks et al. 2013)
- Critical Marine Habitats in High Risk Areas, Princess Charlotte Bay region - 2011 Atlas (Carter et al. 2012).
- Natural and Cultural Resource Profile for the Princess Charlotte Bay Region (QPWS 2008)
- Alluvial Gully Prevention and Rehabilitation Options in the Normanby Catchment and Northern Australia (Shellberg and Brooks, 2013)

**Cover Page Photographs**: Top: Normanby River meanders and mouth at PCB (Peter Pal), Bottom: Normanby River at Battlecamp Road (Christina Howley)

## EXECUTIVE SUMMARY

The Normanby Catchment Water Quality Management Plan is written in accordance with the Australian Government's Framework for Marine and Estuarine Water Quality Protection (the Framework) (DEWHA 2002) and has been funded by the Australian Government Reef Rescue program. This Plan has been produced to identify water quality impacts and to prioritise actions required to maintain or improve water quality in the Normanby catchment and receiving waters. Recent research by CYMAG Environmental (Howley 2010) and Griffith University (Brooks et al. 2013, Shellberg and Brooks 2013)- and consultations with land management agencies, Traditional Owners and other landholders- have identified specific land uses that have significantly altered water quality within the Normanby catchment. There are currently major changes in land use proposed for the catchment, such as coal mining and expanding agriculture and irrigation, which have the potential to further degrade the landscape and water quality if not properly managed.

Elevated nutrient levels have been measured in the Laura River near Lakeland Downs associated with horticulture and fertilizer use. Feral pigs, horses and cattle in wetlands and waterholes have been shown to increase turbidity and nutrient levels and damage riparian and aquatic vegetation. Land use in the catchment has also significantly accelerated erosion and increased levels of sediments entering waterways. Activities that have contributed to the increased erosion include the construction of roads and fences, over-grazing and soil and bank degradation by cattle, changes in fire regimes and tillage for crops. The rates of alluvial gully erosion along some river frontages have increased by at least ten times since the introduction of cattle grazing. The impacts from increased sediment erosion include the loss of downstream aquatic habitat due to the in-filling of downstream channels and lagoons. The impacts of land use on the discharge of suspended sediments and nutrients to the Great Barrier Reef have not been accurately quantified. Increased loads of suspended sediments or nutrients in flood plumes could potentially affect seagrass meadows and coral reef ecosystems at Princess Charlotte Bay (PCB). There is currently little evidence of a decline in the condition of these PCB ecosystems, but monitoring has been limited.

Government investment in water quality improvements in the Normanby catchment must take into account a wide range of connected ecological issues as well as the social, cultural and economic conditions of the Normanby catchment. Long-term, large-scale management actions are needed to address the range of land use issues that are contributing to increased gully and bank erosion. These include grazing management of grass cover, cattle tracks and other soil disturbance along "river frontage" country, weed invasion, altered fire regimes, and road and fence design and maintenance. Concentrated areas of alluvial gully erosion and soils with high erosion risk have been identified for the catchment. Large river frontage paddocks on four main cattle properties in the upper catchment contain the bulk of the eroding gullies, and these frontage paddocks are where cattle tend to congregate. These are the priority areas for investments in large-scale land management changes and intensive rehabilitation actions to reduce sediment yields to downstream rivers, wetlands, estuaries, coasts, and off-shore reefs. Investments in further research and monitoring of the sources and impacts of nutrients and sediments entering the river systems and PCB, and best management practices required to reduce erosion and nutrient run-off are also critical

for the Cape York region to ensure that healthy reefs and aquatic ecosystems are maintained.

Water quality guidelines and targets have been established for some areas of the Normanby catchment. Additional monitoring of water quality and ecosystem health is recommended for some regions, particularly the western catchment area. Draft land condition targets and aquatic ecosystem targets have also been developed.

**High Priority Research and Monitoring Actions**

| Action No. | High Priority Monitoring and Research Action |
|---|---|
| 8.1 | Research on surface and groundwater resources, including aquifer recharge rates and connectivity between groundwater and surface water springs in the Laura Valley and upper Normanby catchment. Develop Water Resource Plan for the upper catchment. |
| 8.2 | Monitor environmental water flows at springs, streams, and rivers; particularly downstream from current and proposed water extraction and impoundment sites. Assess potential impacts on downstream water availability, water quality and environmental values. Develop Environmental Water Flow Guidelines. |
| 8.3 | Develop a "Super Gauge" approach at key river gauge sites to better quantify long-term water, sediment and nutrient loads and actual changes over time. Use continuous surrogate measurements of suspended sediment and bedload with width and depth integrated samples. |
| 8.4 | Improve monitoring of nutrient and sediment loads delivered to PCB from Normanby, Bizant, Kennedy and Marrett River (flood events and tidal flushing). Improve load calculations(sediment and nutrients) and develop loads targets. |
| 8.6 | Research into river sedimentation (sand/silt from gully and bank erosion and in-filling of rivers and wetlands<br>Identify key deposition areas- wetlands and river channels<br>Compare current and historic rates of deposition<br>Quantify the effects on surface water flow and habitat for aquatic animals (fish, turtles) |
| 8.7 | Research appropriate fire regimes for erosion management, weed control, and pasture productivity on hillslopes and river frontage country. |
| 8.8 | Develop effective methods for weed control using innovative techniques (competition, biological, mechanical, chemical). |
| 8.11 | Researching effects of cattle exclusion or spelling in river frontage on vegetation and alluvial gully erosion rates. Large-scale, long-term trials of improved land management practices (cattle, fire, weeds, roads, fences) are needed in areas of alluvial gully erosion and high erosion potential soils along river frontage. Detailed monitoring of erosion and water quality outcomes. Reassess BMPs for erosion reduction and ABCD Framework. |
| 8.12 | Assess the market potential for payments for ecosystem services (soil, carbon, biodiversity retention) to reduce alluvial gully erosion along river frontage at the property and landscape scale. |
| 8.18 | Investigate and identify dominant sources of nutrients and sediments in PCB flood plumes (including sediment tracing and nutrient isotopes) |
| 8.19 | Research coastal erosion processes in the lower Normanby coastal plain, to understand whether this process constitutes a long-term threat to the GBR. |
| 8.20 | Undertake research on the coral reefs surrounding PCB (cores and direct measurement) to determine the relationship between catchment land use and sediment/nutrient export to the reef. |
| 8.21 | Investigate the role of shipping induced sediment re-suspension in the shipping lanes off PCB and the potential impact of the resuspended sediment on nearby reefs. |

## High Priority Management Actions

| Action No. | High Priority Management Action | HEV/HCV area |
|---|---|---|
| 1.1 | Document aquatic sites of high cultural value (HCV) and traditional protocols for use of these areas | Melsonby, Laura River, East/West Quinkin Country, Kings Plain, East/West/Granite Normanby, Rinyirru NP. Others |
| 1.2 | Investigate Indigenous and Environmental Water Allocation for Laura River | Laura River |
| 2.1 | Provide financial and advisory assistance to land managers for detailed grazing property planning and the implementation of integrated actions including the management of grazing pressure, fire and weeds in river frontage country and BMP fencing & road construction. | Priority grazing stations on erosion hotspots, newly acquired indigenous owned properties |
| 2.2 | Spell or permanently exclude cattle from river frontage country at erosion "hot spots". Fencing constructed according to BMPs. Monitor vegetation cover and water quality outcomes. | Priority grazing stations are identified on erosion hotspot maps |
| 2.3 | Increase the number of extension officers with relevant expertise in soil conservation, grazing and horticultural land management. Advise land managers on soil conservation techniques and conduct grazing management workshops including the use of climate forecasting. | Catchment wide |
| 2.4 | Commence socio-economic analysis of current grazing land management compared with alternative practices to reduce sediment and nutrient pollution. | Catchment wide |
| 3.2 | Property based monitoring of water quality impacts to identify priority sites for investment and monitor outcomes from altered land management | Catchment wide- grazing & horticulture properties |
| 3.3 | Provide assistance to landowners to identify and adopt improved management practices to reduce run-off of topsoil, losses of fertilisers to groundwater and surface water and minimize use of pesticides. | Downstream from Lakeland region (Laura River & Boggy Creek) and new developments on East & West Normanby |
| 3.4 | Develop a Water Resource Plan for surface water and groundwater use in the Lakeland region based on a scientific assessment of water resources, current and future uses (stock water, irrigation, domestic) and environmental water flow requirements. | Laura River, East and West Normanby River |
| 4.1 | Conduct detailed review of road practices and develop draft BMP guidelines for main road and track construction and maintenance to reduce erosion in the Normanby catchment, especially on sodic soils. | Catchment wide- Numerous HEV ecosystems are threatened by the cumulative impacts of roads. |
| 4.2 | Workshops with Cook Shire, Qld Main Roads and local operators to trial and adopt the draft BMP guidelines and update/ improve guidelines over time. | As above; On-ground investments should focus on erosion prone soil areas |

| Action No. | High Priority Management Action | HEV/HCV area |
|---|---|---|
| 4.3 | Trial and implement alternative fencing methods to reduce erosion. Assist landholders to identify suitable fence & track locations and erosion reduction methods based on topography & soil types. | As above |
| 4.4 | Upgrade roads to minimize erosion at high erosion sites and assess options for relocating sections of roads adjacent to HEV wetlands | Catchment Wide and localised.<br>Rinyirru (Lakefield) NP |
| 5.1 | Conduct catchment wide coordinated Fire Planning to balance management needs, identify appropriate fire regimes for riparian areas and river frontage country, reduce the area of high-intensity late-dry season burns, and ensure the same areas are not burnt each year. Avoid consistently using riparian zones and river frontage as fire breaks. Monitor annual burns via NAFI and ground observations. | Catchment-wide impacts on downstream HEV areas |
| 5.2 | Provide assistance to landholders to adopt traditional mosaic burning regimes and conduct early-dry season burns to prevent late dry season fires, protect riparian vegetation and river frontage country and minimise impacts on water quality from erosion. | Catchment-wide; priority sites as per mapped erosion hot spots |
| 5.3 | Conduct research into the most suitable fire regime for riparian areas and erodible soils to reduce fire impacts on erosion and water quality. This research should involve property or multiple property scale fire management trials and monitoring of erosion and water quality impacts. | Catchment-wide HEV ecosystems; priority trial sites as per mapped erosion hot spots |
| 6.1 | Approval of mining exploration permits to take into account the cumulative impacts on HEV and HCV aquatic ecosystems (i.e., surface water quality and quantity, groundwater, earthworks, roads, weeds, shipping impacts, metals and contaminants, oils, fish, seagrass, turtles, dugong, dolphin, etc.). | Catchment wide |
| 6.2 | Conduct baseline studies on surface and groundwater resources necessary for assessment of mining impacts including: groundwater and surface water connectivity; baseline water quality outside of existing monitoring areas in the catchment; water flow for environmental needs at downstream HEV sites, and potential impacts on Environmental Values. Develop Environmental Water Flow Guidelines. | Catchment wide- anywhere mining & exploration is proposed |
| 6.3 | Approved exploration and production activities are monitored in detail for impacts on water quality and quantity (environmental flows). Independent monitoring/auditing by 3rd parties. | Catchment wide |
| 7.1 | Continue and increase feral animal control methods at unfenced HEV and HCV areas | Priority HEV and HCV wetlands |
| 7.2 | On-going Treatment to eradicate Hymenachne from Rinyirru NP; identify and target upstream sources in the catchment (i.e. Kalinga Station). | Rinyirru NP |
| 7.3 | Reduce the spread of Sicklepod along river frontage country by providing assistance to landholders for management and researching biological control options. | Laura & Normanby Rivers |

## FIGURES

## ACRONYMS

| | |
|---|---|
| **AIMS** | **Australian Institute of Marine Science** |
| **ANZECC** | **Australian and New Zealand Environment and Conservation Council** |
| **ARMCANZ** | **Agriculture and Resource Management Council of Australia and New Zealand** |
| **BMP** | **Best Management Practice** |
| **CRC** | **Cooperative Research Centre** |
| **CSIRO** | **Commonwealth Scientific and Industrial Research Organisation** |
| **CYMAG** | **Cape York Marine Advisory Group** |
| **CYPAL** | **Cape York Peninsula Aboriginal Land** |
| **CYWAFAP** | **Cape York Weeds and Feral Animal Program** |
| **DAFF** | **Department of Agriculture, Fisheries and Forestry** |
| **DEHP** | **Department of Environment and Heritage Protection** |
| **DEPI** | **Department of Environment and Primary Industries** |
| **DERM** | **Department of Environment and Resource Management** |
| **DEWHA** | **Department of the Environment, Water, Heritage and the Arts** |
| **DNRM** | **Department of Natural Resources and Mines** |
| **DNRMW** | **Department of Natural Resources, Mines and Water** |
| **DSITIA** | **Department of Science, Information Technology, Innovation and the Arts** |
| **EIS** | **Environmental Impact Statement** |
| **EPA** | **Environmental Protection Agency** |
| **EPBC Act** | **Environment Protection and Biodiversity Conservation Act (1999)** |
| **FHA** | **Fish Habitat Area** |
| **GBR** | **Great Barrier Reef** |
| **GBRMPA** | **Great Barrier Reef Marine Park Authority** |
| **HCV** | **High Cultural Value** |
| **HEV** | **High Ecological Value** |
| **NAFI** | **North Australia Fire Information** |
| **NLRWA** | **National Land and Water Resources Audit** |
| **NP** | **National Park** |
| **NRM** | **Natural Resource Management** |
| **OC** | **Organochlorine** |
| **PCB** | **Princess Charlotte Bay** |
| **Qld** | **Queensland** |
| **QPWS** | **Queensland Parks and Wildlife** |
| **RR** | **Reef Rescue** |
| **SCYC** | **South Cape York Catchments** |
| **TO** | **Traditional Owner** |
| **WONS** | **Weed of National Significance** |
| **WQIP** | **Water Quality Improvement Plan** |

**WATER CHEMISTRY ACRONYMS**

| | |
|---|---|
| **DIP** | **Dissolved Inorganic Phosphorous** |
| **DIN** | **Dissolved Inorganic Nitrogen** |
| **DON** | **Dissolved Organic Nitrogen** |
| **ID** | **Insufficient Data** |
| **N** | **Nitrogen** |
| **NOx** | **Oxides of Nitrogen** |
| **NH4** | **Ammonia** |
| **NTU** | **Nephelometric Turbidity Units** |
| **P** | **Phosphorous** |
| **SSC** | **Suspended Sediment Concentration** |
| **TN** | **Total Nitrogen** |
| **TP** | **Total Phosphorous** |
| **TSS** | **Total Suspended Solids** |

# 1 INTRODUCTION

## 1.1 Normanby River

The Laura-Normanby River in southeast Cape York is the fourth largest river system flowing into the Great Barrier Reef. The catchment area covers 24,228 $km^2$. It consists of numerous riverine and wetland systems; one of Queensland's largest conservation areas (Rinyirru (Lakefield) National Park (NP) and the adjacent Jack Rivers NP); many sacred aboriginal sites; extensive cattle grazing country; and rich agricultural land at Lakeland Downs. The river flows north from wet-dry savannah and sandstone escarpment country in the southwest and wet tropical rainforest in the southeast, discharging into Princess Charlotte Bay (PCB). PCB is known for its diverse and healthy marine and coastal ecosystems.

During the wet season, the Normanby River connects via linking branches to the adjacent North Kennedy River. Together these two connected river systems form the larger Normanby catchment area. This plan covers the entire catchment area, however there is a focus on the Laura and Normanby River systems due to the greater body of formal research on these systems. However, the adjacent, connected river systems also have high ecological values and many similar water quality issues and management needs.

## 1.2 Why do we need a Water Quality Management Plan for the Laura-Normanby?

Recent research by CYMAG Environmental (Howley 2010) and Griffith University (Brooks et al. 2013, Shellberg and Brooks 2013)- and consultations with land management agencies, Traditional Owners and other landholders- have identified specific land uses that have significantly altered water quality within the Normanby catchment. This degradation of water quality affects rivers and wetlands within the catchment and has the potential to impact the Great Barrier Reef ecosystem. There are currently major changes in land use proposed for the catchment, such as coal mining and expanding agriculture and irrigation, which have the potential to further degrade the landscape and water quality if not properly managed.

There is currently no strategy to prioritise investments in water quality protection and direct the use of funding from programs such as Reef Rescue in the Normanby catchment or eastern Cape York Peninsula.

**This Plan has been produced to identify water quality impacts and to prioritise actions required to maintain or improve water quality in the Normanby catchment and receiving waters.**

## 1.3 How is this Plan different from a Water Quality Improvement Plan?

Water Quality Improvement Plans (WQIPs) are developed in accordance with the Australian Government's Framework for Marine and Estuarine Water Quality Protection (the Framework) (DEWHA 2002). The key components of the Framework to be included in a WQIP are:

- the environmental values of coastal waters;
- the water quality issues and pollutants of concern;
- water quality objectives for the coastal waters;
- total maximum pollutant loads required to meet the water quality objectives;
- the allocation of pollutant loads to diffuse and point sources;
- river flow objectives;
- management measures and control actions, their time lines and costs; and
- a monitoring, evaluation and reporting program.

The Normanby Water Quality Management Plan has been developed in accordance with the Framework; however, key components such as the setting of total maximum pollutant loads and river flow objectives have not been achieved due to insufficient available data. Where water quality impacts have been identified, changes in land management are recommended to ***improve*** water quality. However, planning to ***maintain*** good water quality and quantity, and to ***protect*** healthy coral reefs and other aquatic ecosystems from current or future threats is critical in the Cape York region and is an equally important component of this plan. Freshwater aquatic ecosystems have also been identified as key targets for water quality improvements in addition to the coastal environmental values targeted in accordance with the Framework.

# 2 CATCHMENT DESCRIPTION

The Normanby River, approximately 200km long, originates in the mountains of the Great Dividing Range in the east and south of the catchment area (16°S; 145°E) and flows north to Princess Charlotte Bay (14°24′ S; 144°8′ E) (Figure 1). Major tributaries include the East Normanby, West Normanby, Laura and Jack Rivers to the southeast and east, and the Mosman, George and Kennedy Rivers in the south and southwest. To the west, the North Kennedy river system includes the Hann River, Moorehead River, Saltwater Creek, and Annie River. The North Kennedy and Normanby Rivers are connected via linking branches within Rinyirru (Lakefield) NP during major flood events. A major lowland distributary, the Bizant River, also connects to both rivers, depending on which is in flood.

The Normanby catchment is located in the wet-dry tropics where climate is characterised by extreme wet (summer) and dry (winter) seasons with 95% of rainfall occurring between the months of November and April. Average annual rainfall in the catchment has been estimated at 1085 mm/year (NLRWA 2001). Sections of the Normanby and its tributaries have ephemeral water flow; late in the dry season, surface water is largely stored in a series of waterholes connected via sub-surface flow through river sands. Wet season flood waters feed extensive wetland systems in the alluvial and marine plains of the lower catchment area and connect otherwise isolated wetlands and adjacent rivers.

## 2.1 Land Use

The resident population for the Laura-Normanby catchment area is less than 500 (Australian Bureau of Statistics, 2006). The major population centres are Lakeland Downs and Laura. Rinyirru (Lakefield), Jack River and Lama Lama National Parks/ Cape York Peninsula Aboriginal Land cover approximately 33% of the catchment. Each of these conservation areas are former cattle stations, and feral cattle continue to access wetlands and rivers within the National Parks.

Grazing remains the most extensive land use occurring on approximately 18,495 $km^2$, or 75% of the Normanby catchment (Reef Report Card 2009). This grazing area has been slightly reduced over the past five years as several stations have been purchased by the Queensland government to be designated Cape York Peninsula Aboriginal Land (CYPAL). Grazing densities are low on Cape York Peninsula on average (~ 1 beast/40 ha). However in the Normanby catchment, productive native pasture properties have modest densities (~ 1 beast/20 ha), river frontages can have moderate densities (>1 beast/10 ha), and improved pastures can have high densities (> 1 beast/5 ha) (Cotter 1995).

Horticulture is currently limited to the rich basaltic soils around Lakeland Downs on the upper reaches of the Laura River. The horticultural area is estimated to cover 35 $km^2$ or 0.15% of the Normanby catchment (Reef Report Card 2009); however this area has been expanding.

Gold mining played a major role in the catchment's history and abandoned mines are scattered across the catchment. Several small mines continue to operate in the upper catchment along the West Normanby and Mosman Rivers. Current coal and mineral exploration permits cover much of the catchment (Figures 8 & 9), and an underground coal mine has recently been proposed in the northern catchment near Bathurst Heads.

Less than 5% of the catchment has been cleared in total according to estimates from satellite images. In 2001, the Qld EPA estimated that 355 $km^2$ (1.5%) had been cleared in the Normanby catchment (Furnas 2003). According to the Great Barrier Reef Outlook Report (2009), 140 $km^2$ are currently cleared. These differences are from vegetation changes over time associated with re-growth after clearing, mixed with periodic new clearing. SLATS documents changes in vegetative cover in the Normanby from 1988 to 2003 and found that clearing rates ranged from 17 to 630 ha/yr. These rates do not account for most of the clearing in the Normanby that occurred between 1945 and 1988. Use of historic air photographs between 1949 and 2006, along with contemporary satellite imagery, need to be used in conjunction to better map past and present areas cleared of vegetation and changes through time in the Normanby. Satellite images also do not pick up the loss of grasses often associated with grazing. Therefore, the extent of these changes has not been quantified.


**Figure 1: Normanby Catchment Area**

## 3 ENVIRONMENTAL VALUES

The quality of water in the Normanby catchment affects the environmental, cultural and productivity values of the river, springs, wetlands and coastal discharge areas. These values come under the term 'Environmental Values' as set out in the Australian and New Zealand Environment and Conservation Council (ANZECC) Freshwater and Marine Water Quality Guidelines (ANZECC 2000). Environmental Values are described as "uses of the environment that are important for a healthy ecosystem or public benefit, welfare, safety or health."

The Environmental Values of the Normanby catchment include cultural values; aquatic ecosystems; drinking water; irrigation; livestock water; and recreational and commercial fishing. These values and their primary locations (discussed in the following sections) have been identified through literature review and consultations with government agencies, Traditional Owner groups, local landowners and managers, and NRM organisations.

## 3.1 Cultural Values

The Normanby River has a large catchment area and its Traditional Owners include the Lama Lama (northern catchment and PCB islands), Kuku Thaypan/Angnarra and Western Yalanji (Laura River region), Balnggarrawarra clan (Melsonby region), the Guguwaarra clan (Normanby Station, Battlecamp), Wumbuwarra, Bulcanwarra, Gabuwarra, Djugunwarra, and Dandiwarra (upper East and West Normanby), and clan groups of the Kalpowar Land Trust, including Munthiwarra (Jack Lakes). Not all Traditional Owners have been identified for the catchment.

### 3.1.1 Cultural and Spritual Values

The Normanby River has important cultural and spiritual values for the Traditional Owners. These values relate to plants and animals such as fish, turtles, and dugongs; spiritual beliefs and ceremonies; sacred story places; and water for drinking and many other purposes. Water is seen as a sacred source of life. The health of the river, and the plants and animals it supports, is integral to the cultural, spiritual and physical wellbeing of the Traditional Owners.

"*Water sites are story places to us. These places are very special. Serpent belongs to the river and looks after the river. Some places the Serpent is very strong. Some of these places are no-go, and some of these places are very healing. People need to know some places you can't go to. If you go there or drink from the water you get sick and the country gets sick.*" (Ron Harrigan, Normanby River Elder)

Peter Wallace, senior custodian on the upper Normanby River, provided the following information about cultural values:

"*Water has very high cultural values to Aboriginal people. For example:*

1. *Clean water for drinking*
2. *Clean water to process wild honey (the honey of the native bees contained in sugarbag)*
3. *Water is healing for Aboriginal people*
4. *Water for births*
5. *Water holes are sacred to Aboriginal people to learn to be traditional healers*

6. *Water hole springs and lagoons are a bank of food sources for people and animals*
7. *Waterfalls have an agreement with saltwater fish species to breed and be a refuge to look after them while they give birth*
8. *Saltwater fish go right up to Laura river*"

"*This water is so important to Aboriginal people because it is their livelihood – their stories and their totems. We, the Normanby River Traditional Owners have white face turtle dreaming. On the Normanby River, there is a white turtle sacred water hole. Up and down river systems there are different dreamings to us Aboriginal people. These water places are our resources.*" Peter Wallace, 2012

The Laura River, from the Dance Festival Grounds to Olive Vale Hole, and the lagoons at Lakefield are important sources of food (mostly fish and turtle) and medicine to the Traditional Owners of the Laura region. These areas are also important for recreational activities, such as camping and celebrations.

The Melsonby Rangers, representing Balnggarrawarra traditional owners from the Battlecamp region of the Normanby River, identified the following values associated with the Normanby River: fishing, traditional foods, camping and other recreational activities, drinking water and stock water, breeding ground for sawfish, and the only place where Coix grass (*Coix gasteenii*) is found (survey by Lucas Armstrong, Melsonby Ranger Co-coordinator, August 2012).

Rock art and sacred sites, including birthing sites on the River, are of particular importance to the Balnggarrawarra Traditional Owners and require documenting and looking after. Other Traditional Owners also identified the need to map sacred sites along the River as a priority for management.

The Traditional Owners of Rinyirru (Lakefield) National Park include the Lama Lama and Kuku Thaypan peoples. The National Park has major cultural significance and features many ceremonial and story places. These include Rarda-Ndolphin (Low Lake), the Hann and Kalpowar crossings, Kookaburra Well Story, and Jane Table Hill, which rises out of the marine plains (www.derm.qld.gov.au/parks/rinyirru-lakefield/culture.html). German Bar Fish Sanctuary in the National Park is also an important place to the Lama Lama people and is now a protected barramundi breeding ground where fishing has been banned (Bassani et al 2006).

The Kalpowar area on the lower eastern side of the Normanby River includes sites of cultural significance including shell middens, rock art and Story Places including Jack Lakes and Barney's Lake. The Muunthiwarra clan (Jack Lakes) has a strong connection to Jack Lakes as a hunting, fishing, and Story place. The "Top Lake" is home to Old Man Lightning (Tim McGreen & Ester Henderson).

Cliff Island and The Flinders Group of Islands in Princess Charlotte Bay also contain sites of significant cultural and heritage value including aboriginal rock art depicting sea turtles, dugongs, fish, and canoes (Bassani et al 2006).


**Figure 2: Identified High Cultural Value (HCV) Aquatic Ecosystems**

*(The cultural values and HCV sites remain under consultation with Traditional Owner groups. Not all sites have been mapped.)*

### 3.1.2 Threats to Cultural Values and Auatic Ecosystems

In addition to the strong cultural and spiritual connections to the River and associated wetlands, the Traditional Owners share many of the same uses and concerns regarding the River as do the non-indigenous residents and visitors.

The Melsonby Rangers are concerned about vehicles crossing the Normanby on Battlecamp Road polluting the river system with sediment and spreading weeds such as sicklepod. They are also concerned about:

- Dead pigs and cows contaminating the water,
- Pigs digging up the banks, spreading weeds and causing erosion,
- Barramundi farms spreading diseases, such as white spot, which they believe led to a massive fish kill in 2011,
- Road erosion from Battlecamp Road and bush tracks, and
- Mining in the catchment. "*The mine will bugger up the river for sure. Fish need to swim past that mine (Bathurst Heads proposed mine) to get upstream.*" (Melsonby Ranger, Aug 2012)

Traditional Owner Nakia Harrigan is also concerned about the erosion caused by poorly constructed roads in the catchment and the effect of road erosion on the Normanby River and adjacent creeks.

Peter Wallace (Senior custodian, upper Normanby), states that "*Weeds, people's cattle, farming on Lakeland Downs, rubbish, and fires burning are things that have an effect and are threatening the river systems. Cattle are the biggest threat to river systems. They drink a lot of water and urinate and defecate in the water hole. If station owners do not fence the river off, or business developers are not investing in the river catchments, then the rivers are at risk and animals and bird species will perish.*"

The Laura River indigenous people listed a number of concerns regarding water quality in the Laura & Normanby Rivers (Sue Marsh, discussion with Laura Rangers, August 2012):

1. There is concern that Lakeland horticulture is impounding too much water and reducing water flow in the Laura River.
2. Contaminants from Lakeland are polluting the river water.
3. Clearing of fence lines on Crocodile Station is increasing the silt burden.
4. The waterholes are silting up.
5. TO's believe the use of motorboats in the river and lagoons at Lakefield NP is damaging the banks and reducing fish stocks; absence of the cleaning guppies in the waterways (as a result of this damage) is blamed for increased diseases in fish (such as the white spot outbreak in Lakefield).
6. Traditional Owners would like nets banned in the river and lagoons. They feel that juvenile fish stocks are being harmed and the ecology disrupted.

In *Lamalama country, Our country, Our culture-way* (Bassani et al 2006), Lamalama elders describe the use of fire to keep country and water clean, and concerns over changes in fire regimes since the introduction of cattle: "*Them cattlemen they burn too, but too many suckers come up after that. They don't burn the aboriginal way. You gotta know the right time to do the burn*."

The Laura Rangers and Melsonby Rangers completed fire plans in 2013 that provide annual burn plans for their country. The plans acknowledge the different priorities and reasons for burning that include infrastructure protection, biodiversity improvement, fire control breaks, and hazard reduction to reduce the impact of late season wildfires.

Climate change and its impact on rivers is also a concern to the Traditional Owners. "*Water quality is very important for fish species to live out their life cycles and reach maturity… Fish and turtles can survive the dry seasons with little water or oxygen, but if dry seasons become longer it will take years for fish species and fresh water turtles to reach adult life again*." (Peter Wallace, 2012)

The indigenous people of the Normanby catchment hold a unique knowledge and understanding of the river's cycles and the connections between water and the plants and animals that it supports. This knowledge is integral to the proper management of the Laura & Normanby Rivers.

High cultural value aquatic ecosystems are shown on Figure 2. Not all cultural values of the catchment have been documented and additional work is required to document cultural sites and the protocols for use of these areas.

## 3.2 Aquatic Ecosystems

Numerous aquatic ecosystems are associated with the Normanby catchment including freshwater rivers, creeks, wetlands, floodplains, estuaries, marine waters and groundwater systems. The values associated with these aquatic ecosystems include: biodiversity, aquatic habitat, cultural connections, aesthetic values, recreational and economic uses (e.g. fishing, stock water, irrigation, tourism).

High Ecological Value (HEV) aquatic ecosystems are defined as "*effectively unmodified or other highly valued systems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations …where the ecological integrity is regarded as intact*" (ANZECC 2000). The management goal for HEV aquatic ecosystems is to ensure that there is no detectable decline in condition (DEWHA 2002).

In the Normanby catchment, there have been no systematic catchment wide surveys to identify areas of high biological diversity or aquatic ecosystem condition. These remain poorly documented for many parts of the catchment outside of conservation areas. Detailed, on-ground assessments of the ecological values and integrity are required to better define HEV areas for the Normanby catchment.

Areas of known HEV aquatic ecosystems within the Normanby catchment are discussed in the following sections and are shown on Figure 3.


**Figure 3: Mapped Areas of High Ecological Value (HEV) Aquatic Ecosystems and Existing Conservation Areas in the Normanby Catchment Area**

### 3.2.1 Freshwater Rivers

The mid- to lower reaches of the Normanby River (Figure 3) are categorized as HEV as they remain largely unmodified, with high conservation values and ecological integrity largely intact. In an assessment of natural heritage values of aquatic ecosystems, biodiversity and hydro-ecology of Cape York Peninsula, Cook et al (2011) identified the following values of the Normanby River:

- High diversity of flow regime classes across the catchment, highly productive system
- Important waterbird habitat, very high number and high diversity of lacustrine and palustrine habitats in a relatively small area
- Extensive inter-tidal flats
- Important breeding location for estuarine crocodiles (*Crocodylus porosus)*
- Contains a species of catfish otherwise limited to west of the Great Dividing Range (*Neoarius paucus* formerly known as *N. midgelyi*)
- Riverine closed forests are an important corridor linking to Wet Tropics and important for regional migration
- Richness and high diversity of Cape York vegetation communities & fauna
- Extensive mud flats
- Important site of mollusk fossils

The Laura River is considered to be a "*slightly to moderately disturbed ecosystem*" (ANZECC 2000) due to the presence of dams, agricultural run-off and accelerated erosion from cattle grazing and roads. The West, Granite, and East Normanby Rivers, and the upper Hann, Morehead, Kennedy and Annie Rivers and Saltwater Creek are also "*slightly to moderately disturbed*" due to widespread erosion, cattle grazing and weeds (Figure 3). Changes in land management are required to improve water quality in these sub-catchments and protect downstream HEV ecosystems (e.g., Shellberg and Brooks 2013).

The upper reaches of some rivers such as the Little Laura and Mosman Rivers (in the areas of the Laura Sandstone) and upper East, West and Granite Normanby Rivers (draining from the Wet Tropics World Heritage Area) are also designated as HEV, as they are highly intact due to their inaccessibility.

### 3.2.2 Wetlands of National Importance & National Parks

Six wetland aggregations within the Normanby catchment have been identified in the Directory of Important Wetlands in Australia (Table 1). Two of these (Marina Plains- Lakefield and Jack Lakes) are also protected as National Parks /Cape York Peninsula Aboriginal Land (CYPAL). In addition, Lama Lama National Park (CYPAL) covers rivers and wetlands in the northwestern section of the catchment adjacent to PCB. The following sections describe these HEV aquatic ecosystems and their susceptibility to changes in water quality.

**Table 1: Wetlands of National Importance in the Normanby Catchment & PCB**

| Wetland Area | Wetland Types* | Criteria met* |
|---|---|---|
| Marina Plains- Lakefield Aggregation (CYP010QL) | B1, B2, B4, B6, B9, B10, B12, B13, B14 | 1,2,3,5 |
| Jack Lakes Aggregation (CYP022QL) | B2, B5, B13, B14 | 1 |
| Violet Vale (CYP023QL) | B2, B5, B6, B9, B10 | 1 |
| Laura Sandstone (EIU 006QL) | B5, B6, B13, B17 | 1 |
| Princess Charlotte Bay Marine Area (CYP017QL) | A2, A7, A8, A9 | 1, 2, 3, 5 |
| Great Barrier Reef Marine Park (GBR003QL) | A1, A2, A3, A4, A5, A6, A7, A9 | 1, 2, 3, 4, 5, 6 |

* See Appendix A for description of Wetland types and Criteria for Listing

#### *3.2.2.1 Princess Charlotte Bay & Great Barrier Reef Marine Park*

Princess Charlotte Bay (PCB) (Figure 4) is recognized both for its diverse coastal wetlands and rich marine ecosystems including extensive seagrass meadows and coral reefs. The high fisheries values of the region led to the creation of the Princess Charlotte Bay Declared Fish Habitat Area for the protection and conservation of barramundi (*Lates calcarifer)* and other fish habitat. The Princess Charlotte Bay Great Barrier Reef Marine Park Authority (GBRMPA) Special Management Area was designated specifically to protect the large dugong (*Dugong dugon)* populations. The bay is also home to a number of threatened and endangered species including snub fin (*Orcaella heinsohni)* and humpback dolphins (*Sousa chinensi)* and marine turtles (Carter et al. 2012).

**Seagrass**

Seagrass meadows are present on the majority of intertidal coastal and reef areas of PCB, covering an area of 11,446 ha (Carter et al. 2012). These seagrass meadows support the commercial and recreational fishing industries at PCB. Reefs such as Clack and Corbett Reef support large populations of foraging green turtles (*Chelonia mydas*) (Dobbs 2001). Seagrass meadows along the coast near the Normanby mouth are shown on Figure 4. Detailed maps of intertidal and reef top seagrass meadows are provided in Appendix B. Sub-tidal seagrass meadows have not been mapped in PCB.

Seagrass meadows are sensitive to changes in water quality, particularly increases in nutrients or sediments, or the presence of herbicides. Seagrass species can also bio-accumulate metals and other contaminants, which can be ingested and accumulated in turtles and dugongs (Haynes 2001, Howley 2001).

**Turtles & Dugong**

Maintaining good water quality and healthy seagrass meadows along PCB is critical to protecting the northern GBR marine turtle and dugong populations. Surveys over a 10-year period indicate that between 25 to 56% of dugongs in the northern GBR region reside in PCB for at least part of their life (CRC Reef Research Centre 2002). The population of dugongs north of Cooktown is estimated at 7,000 to 10,000 animals (*Great Barrier Reef Outlook Report 2009)*.

At least three marine turtle species occur in PCB, all of which are listed as either Endangered or Vulnerable under the Environment Protection and Biodiversity Conservation (EPBC) Act (1999). Princess Charlotte Bay is one of the most important green turtle feeding areas in the GBR Marine Park (Dobbs 2001). A large number of Flatback turtles (*Natator depressus*) forage within the bay and nest on the Flinders Islands and coastal areas (Ian Bell, pers. comm., August 2012). The critically endangered (IUCN 1996) Hawksbill turtle (*Eretmochelys imbricate*) nests on many islands between PCB and the northern boundary of the Marine Park. This entire area is considered to be of international significance for the species (Dobbs 2001).

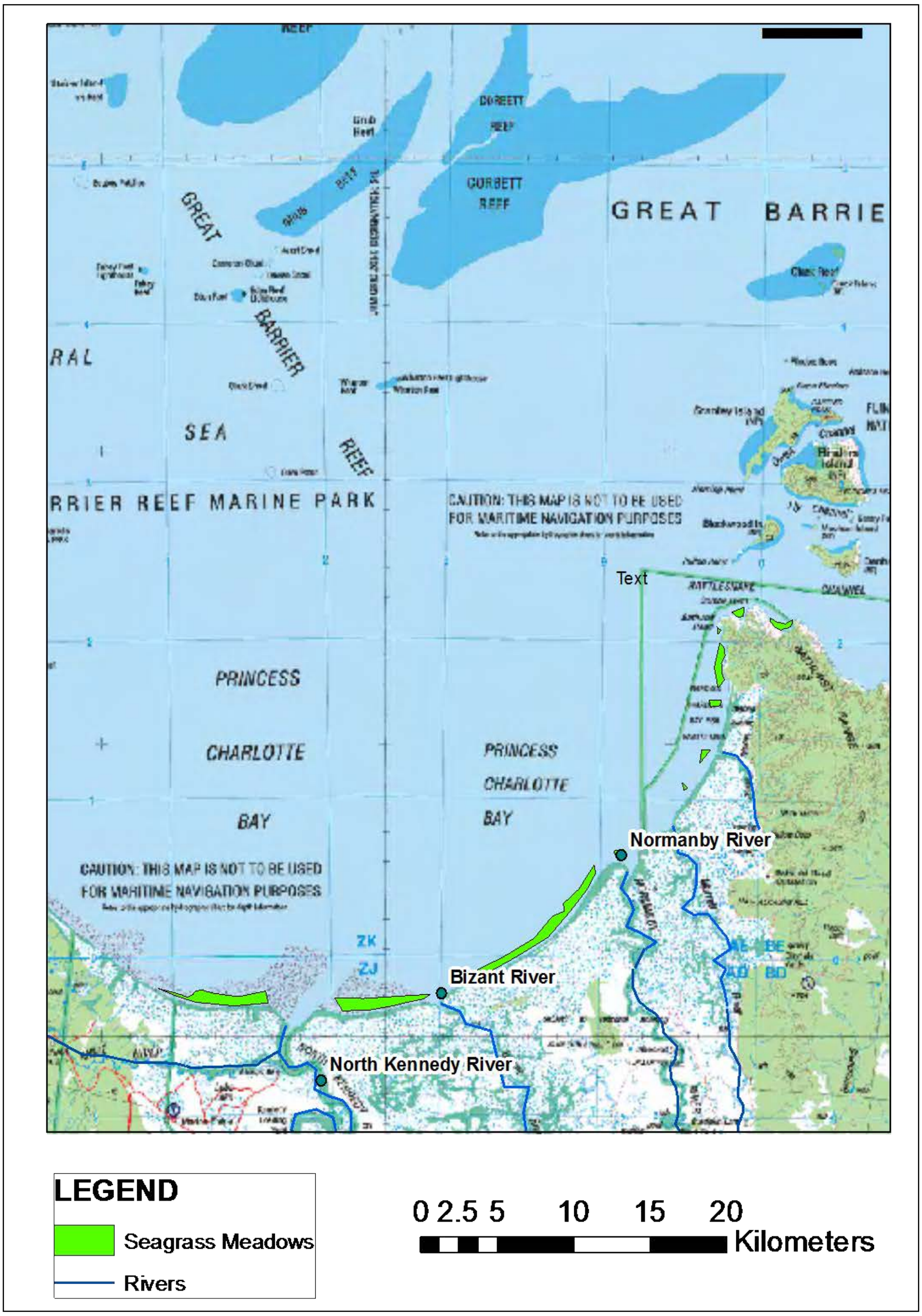


**Figure 4: Princess Charlotte Bay and the Great Barrier Reef**

## Coral Reefs

Reefs in the Princess Charlotte Bay region have significantly higher levels of coral cover, greater coral species diversity, higher coral recruitment and better recruit survival rates compared to similar near shore reefs off the Wet Tropics and other regions of the GBR (Hall & Kenway 2002, Hutchings et al 2008). Abundances of fish on corals in PCB are around three times greater than in the Wet Tropics (Fabricius et al 2005).

The Flinders Group of Islands and their associated reefs are approximately 25 km northeast from the mouth of the Normanby River, while major reefs such as Corbett and Clark are over 30 km away. Despite these distances, major flood plumes from the Normanby and other PCB rivers regularly inundate the islands and reefs (Figure 5). This delivery of nutrients is likely to underpin the productivity of the reef ecosystem; however a significant increase in sediment or nutrient levels in annual flood plumes has the potential to impact on coral health.

**Figure 5**: **Flood Plumes at Normanby River mouth and Wharton Reef, PCB**
**(Photos: C. Howley (left), A. Hogbin (right) 13-2-2009)**

### *3.2.2.2 Rinyirru (Lakefield) NP*

Rinyirru National Park (CYPAL) covers an extensive system of wetlands ranging from above the confluence of the Laura and Normanby Rivers north to Princess Charlotte Bay (Figure 3). Permanent rivers and streams; riverine floodplains; seasonal and permanent freshwater lakes; swamps and saline marshes cover 392,333 ha (QPWS 2008). This includes over 100 permanent freshwater lagoons, numerous ephemeral lakes and lagoons, and one of the largest tidal wetland systems in Australia (Environment Australia 2001).

The freshwater wetlands of Rinyirru support a diverse range of birds, fish, frogs and other fauna, and over 100 species of aquatic plants, including the rare Red Lily (*Nelumbo nucifera*) and the endangered *Astonia australiensis*. The extensive salt flats are critical for many species of migratory birds (Danaher 1995) and are important shorebird habitat (QPWS 2008). The estuary provides important habitat and breeding grounds for mud crabs, barramundi and other fish.

Semi-deciduous mesophyll vine forests along the Normanby and Kennedy Rivers feature significant rainforest species that demonstrate international biogeographic connections (QPWS 2008). The riverine forests linking the Wet Tropics rainforests with rainforest patches south of Silver Plains provide an important corridor for many species migrating across Cape York Peninsula (QPWS 2008).

Rinyirru NP is considered to have a high conservation value in terms of protection of the habitat and feeding grounds of the estuarine crocodile (*Crocodylus porosus*). The freshwater crocodile (*Crocodylus johnstoni*) occurs in permanent waterbodies of the inland sections of the Park (Howley & Stephan 2005). Other species of conservation significance are discussed in Section 3.2.2.6.

The aquatic environments of Rinyirru hold cultural significance for the indigenous clans of the area, including story places, cultural hunting and fishing grounds and sacred sites (Still 2012; Bassani et al 2006).

Rinyirru NP is in generally good condition, with 30% of the area considered to be of very high wilderness quality (QPWS 2008). The western region of the park, including Pelican and Polly's Lakes, is closed to the Public and are believed to be of particularly high Environmental Value. However, the aquatic values of these wetlands have not been documented (Carly Smith, QPWS, pers. comm., 8-04-2013). The marine plains between the N. Kennedy, Bizant and Normanby estuaries are also considered to be of high conservation value and highly intact due to their inaccessibility (Andrew Hartwig, former senior manager, Qld Parks and Wildlife, July 2013). However, recent research has identified significant (naturally driven) erosion in this coastal region (Brooks et al 2013).

Pressures from tourism are increasing and freshwater lagoons have been degraded by feral pigs, cattle and weeds. Road erosion is a continuing threat to water quality, particularly at Old Faithful waterhole (Camp #3) and 6 Mile Waterhole. The road at Kennedy Bend and Catfish waterhole track are also delivering excess sediment into the water. Dust from road traffic is impacting wetland health at wetlands adjacent to roads, such as White Lily and Breeza (QPWS rangers, pers. comm., April 2013).

#### *3.2.2.3 Jack Lakes/ Jack River National Park*

Jack Lakes, part of the Jack River NP, is an inland freshwater lake system covering 808 ha (Figure 3). The lakes flow south into the Jack River, which flows southeast into the Normanby River. The Lakes provide important dry season refuge for migratory waterbirds such as the magpie goose (*Anseranas semipalmata)*, a much valued food source for the Traditional Owners of CYP. Flocks of over 1,000 geese have been observed at Jack Lakes, in addition to a high density of Wandering Whistling-Duck (*Dendrocygna arcuata*), Radjah Shelduck (*Tadorna radjah)* and Pacific Black Duck (*Anas superciliosa*). The wetlands also support large populations of freshwater turtles and fish (Stephan & Howley 2009).

The "Top Lake" at Jack Lakes is a shallow, turbid lake (Figure 6). According to the indigenous land managers, the Top Lake, which is an important Story place, has been rapidly becoming more shallow and turbid in recent years (Michael Ross, pers. comm., July 2012). The source of accelerated sedimentation has not been documented; however, recent research showed that the Jack River was one of the few rivers within the Normanby basin for which the sediment load was dominated by surface soil erosion (Brooks, et. al 2013). Wetland condition assessments by CYMAG Environmental (2007-2009) found the Top Lake to be highly impacted by feral pigs and cattle, which can mobilise soil and accelerate sedimentation (Stephan and Howley 2009).

**Figure 6: Jack Lakes "Top Lake" (Peter Pal Photography, 2007)**

Barneys Lake to the northwest of Jack Lakes is also a significant HEV wetland system, although its values have not been documented.

#### *3.2.2.4 Laura Sandstone*

The perched swamps on the northwestern edge of the Laura Sandstone plateau occur at the top of four tributaries of Shepherd Creek- the headwaters of the Little Laura River (Figure 3). The site is located within the Quinkan cultural area, which contains a large number of art and occupational sites, some of which are older than 20,000 years (Laura Sandstone Wetlands Information Sheet; Environment Australia 2001b).

The very seasonal nature of the wet-dry climate results in the groundwater springs of the Laura Sandstone being important dry season refuges for a variety of animals. These include northern brown bandicoot (*Isoodon macrourus*), Godman's rock wallaby (*Petrogale godmani*), common planigale (*Planigale maculate*), squirrel glider (*Petaurus norfolcensis*), common wallaroo (*Macropus robustus*), agile wallaby (*Macropus agilis*), antilopine wallaroo (*Macropus antilopinus*), eastern grey kangaroo (*Macropus giganteus)*, little red flying-fox (*Pteropus scapulatus*), and dingo (Canis lupus dingo), as well as a wide range of birds, reptiles and amphibians (SCYC, unpublished survey results).

The area is currently used for grazing, and feral pigs are damaging vegetation and disrupting the peat layer in the perched swamps.

#### *3.2.2.5 Violet Vale*

The Violet Vale wetlands occur at the head of a branch of Four Mile Creek, which is part of an extensive braided channel system that drains the eastern side of the Great Dividing Range between Musgrave Station and Mount Walsh (Figure 3). Water flow in the channels is seasonal and during the wet season they commonly overflow their banks and spread out to inundate large areas. The wetlands support regionally rare or uncommon plant communities. The land is currently used for grazing, and as with most wetlands in the Normanby catchment, the wetlands have been impacted by feral pigs and cattle (Directory of Important Wetlands Information Sheet, Environment Australia 2001).

#### *3.2.2.6 Lama Lama National Park/ CYPAL*

Lama Lama National Park/ CYPAL covers 35,560 hectares of Lilyvale Station (north of the Annie river) (Figure 3). "*The park includes highly significant wetlands, coastal and riparian vegetation... There has been little clearing and the tree cover remains virtually intact and contains habitat for vulnerable, rare and* *endangered species including the endangered red goshawk.*" (former Sustainability, Climate Change and Innovation Minister Andrew McNamara, July 2008; http://statements.qld.gov.au/Statement/Id/59121)

The wetlands within the National Park, including the restricted access Goose Swamp and Bull Swamp areas, are of high cultural value to the traditional owners. Fencing cattle and feral pigs out of Goose Swamp has improved wetland condition and increased growth of the red water lily (Gavin Bassani, pers. comm., June 2013).

#### *3.2.2.7 Aquatic Species of Conservation Significance (Freshwater & Estuarine)*

The critically endangered (EPBC 1999) speartooth shark (*Glyphis glyphis)*, also referred to as the Bizant River Shark, is an extremely rare species of fresh or brackish water shark that has been found in the Bizant River in Rinyirru (Lakefield) National Park. Threats to the survival of *Glyphis* sp. include line fishing, gill netting and habitat degradation. The freshwater sawfish (*Pristis microdon),* listed as Vulnerable under the EPBC Act, has been recorded in the Jack River and as far upstream as the Laura River at the Laura township?. The tolerance of these species to changes in water quality and quantity are unknown.

The Vulnerable estuarine crocodile (*Crocodylus porosus*) inhabits much of the Normanby River and its associated wetlands. The near-threatened Radjah Shelduck (*Tadorna radjah*) and Black-Necked Stork (*Ephippiorhynchus asiaticus*) have been documented at Jack River and Rinyirru National Parks. The rare Cotton Pygmy-goose *(Nettapus coromandelianus)* reaches its northern distribution limit in Rinyirru and these wetlands are the only important habitat for the species on Cape York Peninsula (Driscoll 1994).

Plant species of conservation significance documented within the Jack River and Rinyirru National Parks include the following suite of aquatic macrophytes: *Aponogeton elongatus*, *A. queenslandicus*, *Astonia australiensis* and *Vallisneria gracilis* (Stephan & Howley 2009; WildNet Species List for Rinyirru NP).

## 3.3 Drinking Water

Groundwater is the primary source of water for 95% of the population in the catchment area, including the towns of Laura and Lakeland Downs. The domestic water supply for Lakeland Downs is from four (30 m) bores in the McLean basalt fractured rock aquifer. The town supply for Laura is obtained from a deep (190 m) bore in the Gilbert River formations of the Laura Basin.

Within the catchment, three additional groundwater bores are licensed for domestic water supply, and there is one license to pump surface water from Jungle Creek for domestic and stock water. However, licenses are not required to extract groundwater or surface water for domestic purposes. Bores and/or surface water pumps are used for domestic water at stations across the Normanby catchment (DNRM water extraction license records, July 2012).

## 3.4 Irrigation

The quality and quantity of irrigation water sourced from bores and surface water is important for successful horticultural and agricultural enterprises in the Normanby catchment. Horticulture in the catchment is mainly limited to the Lakeland Downs area in the upper reaches of the Laura and West Normanby Rivers where there are rich basalt soils (McLean basalt). The main crops include bananas, passionfruit, papaya, watermelons, pineapples, improved pasture for cattle feed, and a farm forestry project growing teak.

At Lakeland, most of the irrigation water comes from farm dams. Licenses are required to extract surface or bore water for irrigation purposes, but there is no metering of quantities extracted. There are currently a total of 16 licenses to impound water in the Normanby catchment, with most occurring in the Lakeland area (DNRM water extraction license records, July 2012). Many of the dams are located on small intermittent creeks, but the largest - Honey Dam - is located on Bullhead Creek, which flows into the Laura River. The requirement for dam operators is that any base flows entering into the dam are released (i.e. dams are only permitted to store wet season run off) (Peter Siemsen, pers. comm., August 2012). However, it is unknown if this requirement is met at all dams.

The Qld Government has recently proposed to remove restrictions for dam construction above 16 points (<20 $km^2$ each) in the catchment to support agricultural growth in the region (Lakeland Surface Water Management Proposal, 29/4/13).

There are also nine existing licenses to pump water directly from rivers in the Normanby catchment area for irrigation, with a total allocated amount of 2087 ML (DNRM water extraction license records, July 2012). Several additional proposals have been submitted to directly extract water from the Laura River (1850 ML), East Normanby River (5,700 ML/yr), West Normanby River (3,000 ML/yr), and Tableland Creek (7,200 ML/yr).

Groundwater is becoming increasingly relied upon at Lakeland for irrigation as greater areas of land are going into production. There are six licenses currently issued to extract water from 18 bores for irrigation purposes, with a total allocation of 2685 ML per annum (DNRM water extraction license records, July 2012). Water availability, especially during the dry season, may be a limiting factor for agricultural expansion. According to DNRM Water Services, there is only a small reserve of water stored in the basalt that may be allocated for irrigation use, and no further licenses will be approved into the future. Monitoring bores were installed in the basalt in 2010 to investigate aquifer discharge mechanisms and how it responds to rainfall recharge (Peter Siemsen, pers. comm., August 2012).

There is no monitoring of environmental flows above the Coal Seam gauge (25 km downstream from Lakeland). More research on available water resources is needed for the Lakeland region to assess sustainable yields for both agricultural production and the environment. A Water Resource Allocation Plan for the

Laura Basin is needed to determine the amount of ground and surface water that could be taken for irrigation (or other) purposes without affecting springs and environmental river flows, town water supplies, and stock and domestic water.

## 3.5 Livestock Water

Grazing is the most extensive land use in the Normanby catchment. Stock water comes from a variety of sources including groundwater bores, small dams and ponds, and direct river access. In most areas of the catchment, stock have direct access to rivers for their water supply.

The quality of drinking water for stock is important for the condition and health of cattle. Research indicates that when provided with high quality water, cattle will drink more, eat more and gain up to 23% more weight than cattle with poor quality water (Wilms *et al.* 2002). During the dry season, stretches of the Laura & Normanby River accessed by cattle have been shown to have poor water quality (Howley 2010). On sodic soils along river frontages, free access of cattle to river or creek water has triggered and accelerated alluvial gully erosion on steep river banks due to soil disturbance, cattle pads, and/or over grazing (Shellberg and Brooks 2013).

## 3.6 Recreational & Commercial Fisheries

Good water quality and healthy aquatic habitat are vital to the recreational and commercial fishing industries. The Laura-Normanby River system supports a large and important recreational fishery. Many of the visitors to Rinyirru (Lakefield) NP are attracted by the fishing opportunities, and these visitors bring revenue to local communities and National Parks. Fishing is also an important recreational activity and source of food for local residents and Traditional Owners.

Commercial fishing for fish, prawn, crab and lobster at the Normanby estuary and Princess Charlotte Bay provides an important source of local employment and revenue. A total of 59 licenses were granted to fish these waters in 2011. Fish, crabs and prawns caught from the Normanby and Kennedy estuaries and adjacent waters of PCB had a value of over $4.6 million in 2011. Prawns accounted for a large portion of the catch at 284 tonnes, in addition to 26.4 tonnes mud crab, 17.5 tonnes of barramundi and 11.7 tonnes of shark (Fisheries Queensland, Fishery database 2012).

Changes in water quality at PCB could result in losses of seagrass meadows and reduced prawn populations. Mud crabs and barramundi can tolerate fluctuations in turbidity and salinity but are dependent on healthy estuarine and freshwater habitat. Sediment in-filling from accelerated erosion can reduce aquatic habitat. Mud crabs can also accumulate contaminants from water or sediments. Low levels of a banned OC insecticide and polyaromatic hydrocarbons, and higher than average levels of arsenic and chromium have been detected in mud crabs from the Normanby (Negri et al. 2009). The concentrations were not at levels that would pose a risk to human health if consumed.

# 4 WATER QUALITY IN THE LAURA & NORMANBY RIVERS

According to the Great Barrier Reef Water Quality Protection Plan (2009), the main pollutants affecting the health of the Great Barrier Reef are:

- **Suspended Sediments** (soil that has eroded off the land into the water)
- **Nutrients** such as nitrogen and phosphorus (in dissolved or particulate form)
- **Pesticides** such as ametryn, atrazine, diuron, hexazinone and tebuthiuron.

The following sections summarize the current extent of knowledge regarding water quality and impacts of the priority pollutants on the identified Environmental Values of the Normanby catchment and Princess Charlotte Bay.

## 4.1 Nutrients

### 4.1.1 Ambient Nutrient Concentrations

Monitoring of the Laura and Normanby Rivers by CYMAG Environmental between 2006 – 2010 (Howley 2010) documented total and dissolved nitrogen and phosphorous levels (Table 2).

**Table 2: Laura-Normanby River Ambient Nutrient Concentrations (μg/L)**

| | | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen |
|---|---|---|---|---|---|---|
| Laura River N= 126 | min | 6 | <2 | <2 | <2 | 110 |
| | max | 310 | 95 | 73 | 1300 | 2000 |
| | mean | 42 | 11 | 6 | 124 | 469 |
| Normanby River freshwater N= 87 | min | 4 | <2 | <2 | <2 | 90 |
| | max | 110 | 19 | 47 | 210 | 1400 |
| | mean | 25 | 4 | 6 | 19 | 235 |
| Normanby River estuary N = 29 | min | 9 | <2 | <2 | <2 | 150 |
| | max | 71 | 13 | 54 | 130 | 560 |
| | mean | 32 | 5 | 17 | 46 | 284 |

Source: CYMAG 2006-2010, collected during base flow and some flood events (Howley 2010)

During base flow conditions nutrient levels were generally low in the main Normanby River and the East Normanby River. However, elevated ammonia and chlorophyll-a concentrations were detected during the dry season at some monitoring sites including the East Normanby River, the Normanby River at Battlecamp Rd and 12 Mile Waterhole in Rinyirru (Lakefield) National Park. High numbers of cattle congregating around these drying stretches of river may contribute to the high ammonia levels. High levels of algal growth (indicated by chlorophyll-a) can degrade the habitat values of dry season waterhole refugia and the quality of stock water.

Total and dissolved nutrient levels were up to ten times higher in the Laura River downstream from Lakeland than elsewhere in the catchment. Mean nitrogen oxide concentrations in the Laura River at Lakeland were 390 μg/L compared to a Normanby catchment-wide freshwater mean of 22 µg/L. Nutrient levels remained elevated 20 km downstream from Lakeland at Carrolls Crossing but decreased with distance from Lakeland (Howley 2010). Elevated nitrogen oxide levels in the Laura River at Lakeland indicate that surface water run-off or groundwater leaching of fertilisers from farms is impacting on water quality. However, basaltic soils around Lakeland have higher nutrient levels than downstream sodic soils (Grundy and Heiner 1994; Shellberg, unpublished data) and erosion of these soils due to farming and grazing practices, plus natural surface water run-off and groundwater leaching may also contribute to the elevated nutrient levels.

Elevated nutrient levels can impact the Laura River by increasing algal growth, which depletes oxygen and degrades aquatic habitat values and stock water quality. Algal blooms have been observed during the dry season within the Laura River between Lakeland and Carrols Crossing. Nitrite toxicity to fish could be a concern at periods of maximum concentrations.

Mean ambient nutrient concentrations at the Normanby estuary exceed mean concentrations from the freshwater reaches of the River (Table 2). Maximum concentrations of dissolved inorganic nitrogen (NOx and NH4) were detected within the estuary during the dry season (Howley 2010). These data and visual observations indicate that tidal flushing from coastal saltpans and the associated bank erosion may be a significant year round source of nutrients and sediments to the estuary and PCB.

#### 4.1.2 Flood Event Nutrient Concentrations

High nitrogen and phosphorous concentrations have been detected at freshwater sites during major flood events (Table 3). Monitoring across the catchment during 2012 and 2013 flood events detected nutrient concentrations that typically would be associated with highly disturbed catchments (i.e. intensive grazing and agriculture). The sources of these nutrients and their relationship with suspended sediments are uncertain. The highest concentrations of dissolved inorganic nutrients were detected in the upper Laura River and are likely to result from a combination of fertiliser use and the release of nutrients from basalt soils (accelerated by tillage and cattle grazing). Total and particulate N and P concentrations were highest in the middle Laura River between the Dance Festival Grounds and Laura town. Potential sources of nutrients to the mid-Laura River area may include concentrated gully erosion along the river reach upstream of the Dance Festival Grounds (Brooks et al. 2013; Shellberg and Brooks 2013) and late dry season (hot) fires.

Gully, bank and road erosion in the East and West Normanby catchments is a significant source of sediment to these branches of the river during floods and has been accelerated by grazing land use (Brooks et al. 2013; Shellberg and Brooks 2013). This erosion may also increase nutrient concentrations and loads in the upper catchment.

The productive freshwater wetlands and coastal saltmarshes may play a significant role in supplying nutrients to the estuary and PCB flood plumes. Coastal erosion may also be a significant source of nutrients to flood plumes.

**Table 3: Maximum Nutrient Concentrations[1] (µg/L) during Flood Events in the Laura & Normanby Rivers**

| SITE | TN | PN | DIN2 | DON3 | TP | DIP | DOP3 | PP |
|---|---|---|---|---|---|---|---|---|
| Normanby estuary[4] | 718 | 390 | 107 | 379 | 130 | 30 | 10 | 100 |
| Kalpowar | 580 | 160 | 73 | 360 | 70 | 40 | 1 | 40 |
| East Normanby | 1800 | 300 | 327 | 390 | 230 | 20 | <20 | 90 |
| West Normanby | 1290 | 850 | 241 | 360 | 340 | 50 | <20 | 170 |
| Mid-Lower Laura River (Carrolls Crossing-Laura) | 3980 | 3500 | 777 | 320 | 540 | 50 | 40 | 510 |
| Upper Laura River (Lakeland region) | 2470 | 1790 | 1180 | 960 | 600 | 220 | 40 | 390 |

1 Collected during 2012 and 2013 flood events (Howley et al unpublished data)
2 NH4+NOx
3 Dissolve Organic Nitrogen (DON) and Phosphorous (DOP)
4 Includes flood event data from the Normanby, Bizant and Kennedy River mouths

### 4.1.3 Princess Charlotte Bay Flood Plumes and Nutrient Loads

During flood events, plumes of sediment, nutrients and organic matter from the Normanby River, other rivers and distributaries (Bizant, Kennedy, Marrett Rivers) and the coastal plain are discharged into Princess Charlotte Bay and can extend to the Great Barrier Reef (Figure 7).

**Figure 7: Normanby and Kennedy R. Flood Plumes, Feb 2007 (MODIS satellite image)**

High concentrations of nutrients, particularly dissolved inorganic nitrogen, have been detected in flood plumes at PCB (Howley & Devlin, unpublished data). As with the concentrations within the river during floods, the primary sources of these nutrients in PCB and how much they have been influenced by land use is not known.

Estimates of total nutrient loads discharged to Princess Charlotte Bay have been calculated based on flood monitoring conducted at Kalpowar Crossing (50 km upstream from the Normanby mouth) and various catchment models (Table 4). These estimates do not take into account discharge from the adjacent and connected North Kennedy River and Bizant Rivers, which also receive floodwater from the Normanby. They also do not include nutrient sources from the lower floodplain, coastal erosion and other PCB tributaries. It is difficult to accurately assess current nutrient (or sediment) loads discharged to Princess Charlotte Bay or to monitor changes in nutrient or sediment loads over time, due to the complex and poorly understood interactions in the lower catchment and the lack of measured water discharge volumes at the end of the system.

**Table 4: End of System Nutrient Loads Estimates (tonnes/year)**

| Source | Data Utilised | TN | DON | DIN | TP | DOP | DIP |
|---|---|---|---|---|---|---|---|
| Furnas 2003 | Simple Model using AIMS data 1999-2000 – Kalpowar Crossing | 1960 | 394 | 846 | 208 | 29 | 21 |
| Joo et al, 2012 | 2006-2009 – Kalpowar Crossing DERM TSS and gauging data | 711- 1814 | -- | 54 – 93 | 84 - 168 | -- | 16 – 30 |
| Kroon et al, 2011 | Modified Sednet/ANNEX model | 6700 | 1200 | 950 | 670 | 61 | 13 |

Further research is needed on the source, transport and fate of nutrients in the Normanby catchment, nutrient loads, and sources of nutrients in flood plumes, in order to understand potential land-use impacts on HEV aquatic ecosystems and for targeting management actions.

## 4.2 Suspended Sediments

### 4.2.1 Suspended Sediment Concentrations & Water Turbidy

Monitoring of suspended sediment concentrations and/or turbidity has been conducted in the Normanby catchment by the Qld government (DNRM/DSITIA) at official stream gauging sites (Joo et al 2012; Qld Govt unpublished data), AIMS at Kalpowar Crossing (Furnas unpublished data), and CYMAG and Griffith University at numerous DNRM gauge and other monitoring sites (Howley 2010, Brooks et al 2013, Howley unpublished data).

Turbidity concentrations at Laura and Normanby River freshwater sites are generally low (<10 NTU) throughout the dry season. Short-lasting peaks in turbidity and suspended sediments occur during and immediately after high rainfall events. The estuary is relatively turbid year round with a dry season median turbidity value of 23 NTU (wet season median = 41 NTU) compared to a lower Normanby (freshwater) dry season median value of 6 NTU (wet season median = 69 NTU) (Howley 2010, Furnas unpublished data and DSITIA gauging station data). These elevated turbidity levels result primarily from outgoing high tides eroding sediments from the river banks and adjacent mudflats.

At the catchment scale, maximum suspended sediment concentrations (SSC or TSS) are detected during flood events in the upper segments of the Laura and Normanby catchments (Figure 8) and are largely associated with the erosion of alluvial gullies and small creeks cut into erodible floodplain soils. SSC values at an outlet of an alluvial gully along the middle Laura River during several flood events averaged 36,247 mg/L (n=26) (Shellberg unpublished data). A maximum SSC of 7064 mg/L was recorded in a small tributary of the Granite Normanby fed by alluvial gullies (Howley unpublished data). SSC concentrations in the Laura, East and West Normanby Rivers regularly exceed 1000 mg/L during flood events. Suspended sediment concentrations decrease downstream from the

Normanby and Laura confluence at Rinyirru/ Lakefield National Park due to dilution and/or settling out of sediments. The maximum SSC recorded at Kalpowar Crossing in Lakefield National Park is 300 mg/L (median flood event value 42 mg/L) and the maximum SSC concentration detected at the mouth of the Normanby, Bizant, or Kennedy Rivers is 108 mg/L (median event value 43.4 mg/L) (combined AIMS, Howley, DSITIA unpublished data). Many of these samples were collected from the edge of the river; average concentrations may be higher if samples were integrated through the width and depth of the channel.

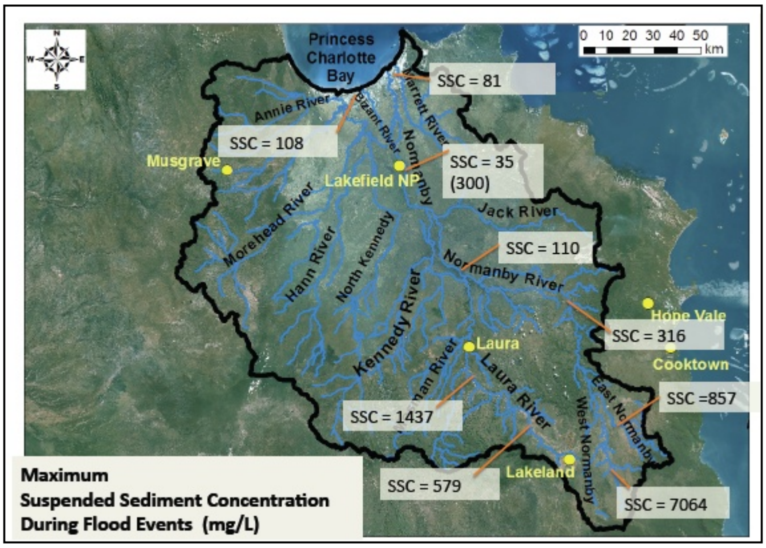


**Figure 8: Maximum Suspended Sediment Concentrations measured during flood events at various locations across the Normanby catchment** (DSITIA gauging station data; Furnas unpublished data; Howley 2010; Howley unpublished data)

### 4.2.2 Dominant Sources of Suspended Sediments and Erosion "Hot Spots"

The dominant erosion processes contributing suspended sediments to the Normanby River and its tributaries are bank erosion (primarily small alluvial tributaries widespread across the catchment) and gully erosion (Brooks et al 2013).

A significant increase (10x) in alluvial (floodplain) gully erosion has been measured post-European settlement, which has been associated with the introduction of cattle, overgrazing, and soil disturbance (Brooks et al. 2013, Shellberg and Brooks 2013). Alluvial gully erosion occurs primarily in areas of sodic soils on elevated floodplains and terraces (river frontage) and is actively eroding more than 7000 ha of land in the Normanby catchment (Brooks et al. 2013, Shellberg and Brooks 2013). Areas of concentrated alluvial gully erosion occur along the West Normanby and Granite Normanby Rivers in the southeast (Figure 9; Figure 17). Other major areas of alluvial gully erosion include the East & West Normanby confluence and tributaries of the Normanby River upstream from Battle Camp Road. Along the Laura River, the worst gully erosion is between the Laura Dance Festival grounds and Carrolls Crossing. To the west, a modest density of gullies occurs on the Mossman, Hann & North Kennedy Rivers and in the upper catchment of Saltwater Creek (Figure 9).

The human land-use impacts on the rates of bank erosion and colluvial (hillslope) gully erosion have not been quantified in the Normanby. However colluvial footslopes and hillslopes have been similarly affected by over grazing, soil disturbance, and fire changes, which could have accelerated colluvial gully erosion from increased water runoff and reduced soil protection. Small channel banks could have been similarly disturbed by cattle hoofs, loss of perennial grass on banks, increased water runoff, and channel adjustments from pulses of coarse sand sediment supplied from upslope alluvial and colluvial gullies.

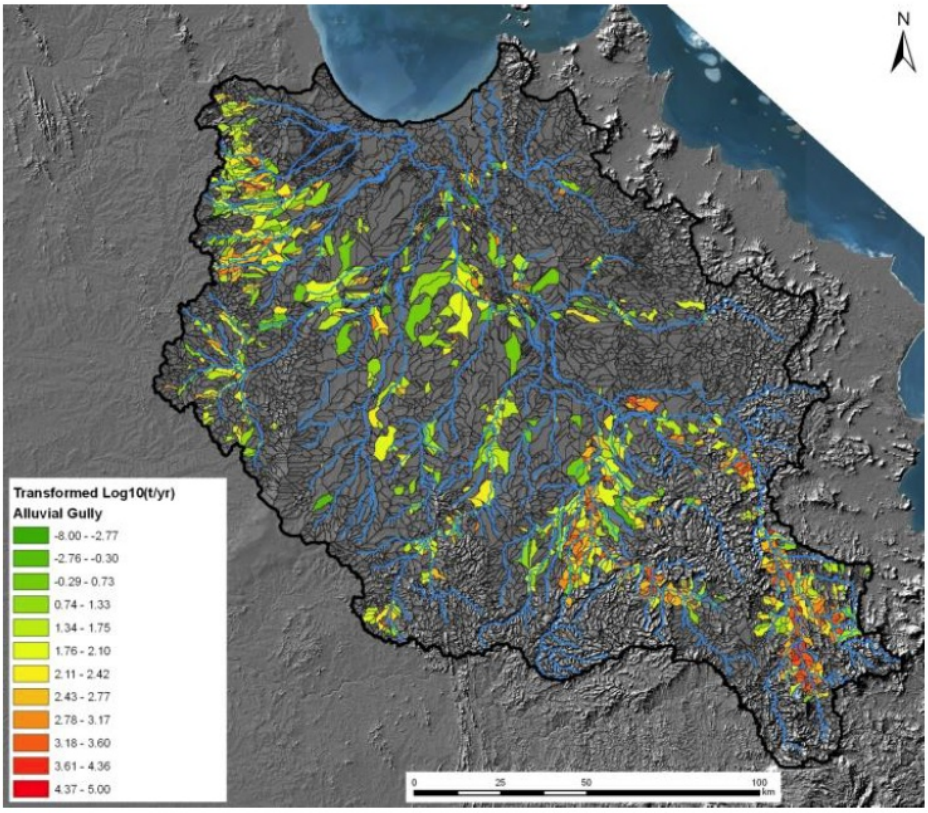


**Figure 9: Distribution and rates of erosion of alluvial gullies in the Normanby catchment.** Red areas indicate the highest rates of erosion.
(J. Spencer, Brooks et al 2013)

### 4.2.3 Sediment deposition within the catchment

Recent research by Griffith University indicates that suspended sediments are being deposited predominantly on in-stream benches within mainstem river channels, as well as on larger overbank floodplains in the lower catchment. In-channel pools and off-channel lagoons are also areas of major sedimentation, but rates have not been well quantified. Brooks et al. (2013) dated sediment layers in river benches along the Normanby River and found that most benches were deposited after European settlement, possibly indicating large amounts of sedimentation of these systems from increased gully and bank erosion. Many river channel pools are also choked with slugs of sand, at least partially influenced by accelerated erosion in the catchment.

Observations by long-term land-owners and historical photos also indicate that some river channels and lagoons have been subject to rapid in-filling over the past 100 years (Paddy Bassani,, Michael Ross, Thomas George, pers. comm., 2012-2013; Old Laura Homestead photos early 1900's). It is likely that increased sedimentation has coincided with the increased rate of gully erosion (10x increase in some places) resulting from changes in land use (e.g., cattle grazing, fire regimes, weeds, roads, fences)(Brooks et al. 2013, Shellberg and Brooks 2013). The Environmental Values most threatened by the increased deposition of sediments include the rivers and wetlands of Rinyirru/ Lakefield National Park, where aquatic habitat may be lost or altered.

The mid-catchment river channels, benches, and floodplains act as buffers to minimize the amount of sediment (especially silt and sand) from the upper catchment reaching Rinyirru/ Lakefield National Park, Princess Charlotte Bay and the Great Barrier Reef. However in the future, these deposits may also represent a large source of sediment available to be resuspended during major flood events. Reducing disturbance to aquatic and riparian vegetation will help to maximize the residence time and buffering capacity of these channel systems.

Further work is required to document the major deposition zones along the channel system, the rate of in-filling of channel, wetland and lagoon systems, and increases in sediment deposition associated with post-European land use.

#### 4.2.4 Suspended Sediment Loads and Discharge to PCB

Estimates of suspended sediment loads at Normanby gauging stations calculated from DERM, AIMS, CYMAG and Griffith University data are presented in Table 5 along with the most recent modeled load estimates (Brooks et al 2013).

Estimates of sediment loads discharged to Princess Charlotte Bay have been calculated from the data collected at Kalpowar Crossing and from more recent sediment budget models (Kroon et al, 2011; Brooks et al, 2013). The standard SedNet model was previously used to calculate a Normanby catchment suspended sediment load of 1100 ktonnes/year (Kroon et al, 2011, Brodie et al, 2010). The more recent empirically-based sediment budget model estimated a sediment load of 1400 ktonnes/year above the coastal plain plus an additional (potentially larger) sediment contribution from coastal erosion (see additional details in Text Box below) (Brooks et al 2013).

As described in Section 4.1.3 in relation to nutrients, it is impossible to accurately assess sediment loads discharged to Princess Charlotte Bay based on the Kalpowar gauge data. The Kalpowar gauge only measures a fraction of the total Normanby water and sediment discharged to Princess Charlotte Bay (See Brooks et al. 2013, Appendix 9). In addition to losses around the gauge, significant coastal sediment sources are not taken into account.

**Table 5: Estimated Average Annual Suspended Sediment Loads (tonnes/year) at Select Gauges**

| Gauge Site[1] | River / Site | Catchment Area (km$^2$) | Annual Suspended Sediment Load[2] | Annual Suspended Sediment Load[3] | Modeled suspended sediment loads[4] |
|---|---|---|---|---|---|
| **105105A** 1969-2013 | East Normanby / Mulligan Hwy | 297 | **Ave: 65,732** Median: 46,545 StDev: 67,115 | | **53,000** |
| **105106A** 1970-1989 | West Normanby/ Mt. Sellheim | 839 | **Ave: 247,070** Median: 90,004 StDev: 314,478 | | **450,000** |
| **105101A** 1967-2013 | Normanby/ Battle Camp | 2302 | **Ave: 261,751** Median: 240,807 StDev: 238,737 | | **738,000** |
| **105102A** 1968-2013 | Laura/ Coalseam Creek | 1316 | **Ave: 135,482** Median: 88,468 StDev: 154,118 | | **190,000** |
| **105107A** 2005-2013 | Normanby/ Kalpowar Crossing | 12,934 | **Ave: 126,015** Median: 109,165 StDev: 77,465 | **Ave: 124,667** Median: 104,000 StDev: 78,079 | **650,000** |

1 The years of operation and available data varied for each gauge
2 Empirical data reviewed in Brooks et al. 2013
3 Joo et al 2012; Kalpowar Crossing monitoring (2006-2009)
4 Sediment budget model (Brooks et al 2013)

**Table 6: Empirical estimates of annual suspended sediment loads at the Kalpowar gauge between 2006 and 2012**

| **Water Year (July-June)** | **Annual Total Suspended Sediment Load (tonnes/yr)** Brooks et al 2013 Pooled DERM TSS Data, One Rating Curve | **Annual Total Suspended Sediment Load (tonnes/yr)** Joo et al. (2012), DERM TSS Data, Loads Interpolated and Calculated at Event Scale |
|---|---|---|
| 2006 | 145,270 | N/A |
| 2007 | 70,355 | 59,000 |
| 2008 | 175,037 | 211,000 |
| 2009 | 89,184 | 104,000 |
| 2010 | 109,165 | N/A |
| 2011 | 264,125 | N/A |
| 2012 | 28,967 | N/A |

Coastal erosion has been shown to be a dominant source of sediment to the bed of Princess Charlotte Bay (Brooks et al 2013). Although this coastal erosion may be predominantly driven by tides, it may also be a significant factor in flood plume sediment loads, particularly during extreme flood events that coincide with high tides or coastal rainfall.

Further monitoring and research is required to better understand the sediment erosion and deposition processes occurring in the Normanby catchment and to empirically measure sediment and nutrient loads delivered to the Great Barrier Reef.

**Normanby Sediment Budget Model**

(Andrew Brooks & Jon Olley, Australian Rivers Institute, Griffith University)

A recent study (Brooks et al., 2013) developed a sediment budget for the catchment using a combination of field-based measurements, sediment tracing techniques and catchment scale modeling. Contrary to previous models, they showed that hillslope erosion is only a relatively minor component of the sediment budget (< 10%). The previous modeling-based studies (Prosser et al., 2001; Brodie et al., 2003) identified hillslope erosion as supplying around 90% of the sediment delivered to the river system. Brooks et al., (2013) estimated that gully erosion contributes ~37% to the suspended sediment load and channel bank erosion from small alluvial channels ~54%.

Sediment source tracing using sediment geochemistry indicated that these upper catchment derived sediments only contribute about 9% of the sediment currently present on the bed of Princess Charlotte Bay (PCB). The geochemistry indicates that the bay sediments are comprised of terrestrial sediments (46 ± 5%), with marine derived carbonates 28 ± 2% and quartz silt/sand (of indeterminate origin but a significant proportion of which is from the rivers) contributing 26 ± 3%. Of the 46% derived from terrestrial sources the largest contributions are predicted to come from the Bizant River (52 ± 1%) and Coastal Plain (30 ± 1%), with the remaining 18% derived primarily from the Normanby-Laura River. The sediment geochemistry shows that the dominant terrestrial source is the lowland floodplain/coastal plain in the vicinity of the Bizant and North Kennedy Rivers. This finding supports a preliminary conceptual model of this coastal plain first proposed by Chappell (1982), in which he described how alluvial sediments were backed up behind a coastal beach ridge system that developed in the mid Holocene when sea level was up to 1 m higher than present. The combination of sea-level lowering since the mid-Holocene, coupled with major erosion of the Bizant River channel, as it increasingly becomes the major distributary of the Normanby River, would appear to be driving the erosion.

The measured percentages of sediment origin in PCB bed sediments do not necessarily represent the relative proportion or variability of sediment sources in actual freshwater floods events that could deliver sediment to the GBR. These flood plume measurements are currently ongoing as part of recent research (Howley et al. unpublished data). Lower floodplain/coastal erosion and transport processes can operate throughout the year due to tides, in contrast to episodic floods, thus dominating measured percent sediment sources on the bed of PCB. They might or might not deliver suspended sediment to the GBR, unlike freshwater flood plumes, depending on the transport mechanism or events.

The dominance of the lowland floodplain and coastal plain as a source of terrestrial sediments to the bay does not lessen the importance of upper catchment sediment sources, in terms of impact on the health of the aquatic systems in the catchment. The lower catchment includes the largest aggregation of wetlands listed on the Directory of Important Wetlands on the East Coast of Australia (other than the Great Barrier Reef). Sediments derived from the upper catchment can have a significant effect on water quality and habitat in these floodplain wetland systems.

The sediment budget study showed that a significant proportion of the suspended sediment delivered to the stream network in the Normanby Basin is being stored within the channel network (~14% of all suspended sediment delivered to the stream network), with a further 41% predicted to have been deposited within the floodplains and wetlands of the lower Normanby basin (primarily within Lakefield National Park). The residence time of the fine sediment stored within the channel zone is much less than that stored in the floodplains – 10's - 100s of years compared with 100's – 1000's of years for sediment stored in floodplains. (i.e. before it is ultimately reworked through the catchment and delivered to PCB). Hence, it is possible that the full effect of land-use induced elevated sediment loads from the upper catchment (i.e. upstream of Lakefield National Park) has yet to be fully realized at the outlet of the rivers feeding into PCB, due to the fact that it is being stored within the channel zone. This highlights the importance of managing disturbances within the channel network that have the potential to accelerate the turnover of sediment.

## 4.3 Pesticides

Very low levels of herbicides (diuron, atrazine, simazine and the phenoxy-acetic acid herbicides 2,4-D and 2,4,6-T) have been detected in the Laura River downstream from Lakeland. Herbicide concentrations were highest in the vicinity of Lakeland below Broken Dam Station and Bullhead Creek, which receives run-off from much of the agricultural land. Reduced concentrations of these herbicides were detected approximately 25 km downstream at Crocodile Station.

The concentrations of all herbicides were well below the Guidelines for the Protection of Aquatic Ecosystems (ANZECC 2000) and are not likely to have a significant impact on aquatic ecosystems in the Laura River at current concentrations and base flow water discharge rates. However, some of the contaminants detected can be accumulated in fish to higher concentrations than that occurring in the water. It is recommended that monitoring for herbicides continues along the Laura River (important fishing grounds for the local community) particularly with the increase of horticulture in the area.

No herbicides have been detected in water samples collected at Kalpowar Crossing or the Normanby estuary (Howley 2010), and pesticides are not estimated to be present at detectable loads in the Normanby River flood discharge (Kroon et al. 2011). However, diuron, atrazine, simazine, and hexazinone have been detected near Hannah Island in northwestern region of Princess Charlotte Bay during a major flood event (Shaw et al. 2010). Further monitoring is necessary to determine the source of these herbicides. The banned organochlorine (OC) insecticide trans-chlordane was also detected in one Normanby River crab sample (Negri et al. 2009). Historical use of this chemical may have resulted in the settlement of chlordane into Normanby River sediments, where it can bio-accumulate in animal tissues. The concentrations detected are not at levels that would pose a risk to consumers, however additional sampling of estuary sediments and/or biota for this highly persistent pesticide is recommended.

Despite the low levels of pesticides detected at Hannah Island and crab tissues, recent water and sediment sampling in the Normanby catchment suggests that the current low levels of herbicides & pesticides in the Laura River are unlikely to impact aquatic ecosystems downstream at the Normanby estuary or the Great Barrier Reef.

# 5 LAND USE IMPACTS ON WATER QUALITY

## 5.1 Cattle Grazing

**Figure 10**: **Cattle on the Granite Normanby (J. Shellberg, 2013)**

Grazing occurs on approximately 75% (18,495 km$^2$) of the Normanby catchment (Great Barrier Reef First Report Card, 2009 Baseline) and is an important part of the history, lifestyle and economy of this region.

Cattle density on grazing lands is estimated at 1 beast/50 ha on average for the Normanby catchment (Cotter 1995; Brodie and Mitchell 2005). However this average includes both productive and unproductive grazing land. In the Normanby catchment, productive native pasture properties can have modest densities (~ 1 beast/20 ha), river frontages can have moderate densities (>1 beast/10 ha), and improved pastures can have high densities (> 1 beast/5 ha) (Cotter 1995). Despite the low but variable density, the cumulative impact of over 100 years of cattle grazing is significant, particularly around rivers and wetlands where cattle congregate.

Without best management practices, cattle can directly and indirectly impact on water quality causing increases in nutrient loads, erosion, sedimentation, and bacteria. Direct impacts from cattle include reduction of grass cover, disturbance of river banks and destruction riparian vegetation. Indirect impacts associated with the grazing industry include the spread of weeds and altered fire regimes, both of which can reduce perennial grass cover and increase water and sediment run-off. Road, fence and track networks to service the industry also cause erosion. A more detailed analysis of the impact of cattle and other land-use disturbances in the Normanby is provided by Shellberg and Brooks (2013).

Deep cattle pads worn into steep river banks and adjacent areas cut into highly erodible sodic soils and can initiate alluvial gully erosion ("breakaways"). Accelerated water run-off from reduced grass cover also can promote the development of alluvial gullies on floodplain margins (Brooks et al. 2009; Shellberg 2011, Shellberg and Brooks, 2013). **The rate of gully erosion along river frontage areas has increased by at least ten times in some parts of the upper catchment since the introduction of cattle** (Brooks et al. 2013; Shellberg and Brooks, 2013).

The congregation of cattle in and around streams and wetlands in the catchment has been linked to increased turbidity, nutrients and bacteria and may lead to increased algal growth during the dry season (Howley 2010, Stephan and Howley 2009). Cattle are attracted to most permanent waters in the catchment, including large numbers of feral cattle that exist within National Park areas. Managing cattle to avoid further erosion and degradation of rivers and wetlands is crucial to maintaining and improving water quality in the Normanby catchment. Removing cattle from National Park areas is critical for protecting HEV waters.

### 5.1.1 Grazing Impacts on Environmental Values

Cattle grazing impacts on the Environmental Values of the Normanby include:

- **Widespread erosion** is initiated or accelerated by cattle grazing on hillslopes, river banks and gully prone areas.
- **Increased suspended sediment loads and turbidity levels** results from catchment disturbance and cattle accessing water holes during the dry season at many unfenced locations
- **Increased sedimentation** from settling of sediment within channels, wetlands, floodplains and coastal areas downstream at Rinyirru National Park, Princess Charlotte Bay and the Great Barrier Reef can reduce the habitat values and water quality for fish and other aquatic life.
- **Destruction of riparian vegetation** from cattle grazing and trampling of vegetation while accessing water holes during the dry season at many unfenced locations (e.g., Jack Lakes; Figure 11, the Laura River and the Normanby River).
- **High levels of algal growth** have been documented at waterholes frequented by cattle, and may be related to cattle urine and manure. Increased algal growth reduces the quality of water used for stock water and domestic use.
- **High levels of bacteria** (faecal coliforms and e-coli) have been detected in the Normanby River at sites frequented by cattle

**Figure 11**: **Cattle hooves degrade soil and edge vegetation at Jack Lakes**

### 5.1.2 Grazing Management

Surveys of management practices have been conducted for seventeen properties in Cape York (mostly in the Normanby catchment area) as part of Reef Rescue. The categories surveyed included stocking rate, pasture spelling, grazing management, groundcover, fire management, off-stream watering, subdivision for managing land condition, riparian zone (frontage) management and record keeping. The results have been scored against the Reef Rescue ABCD Framework for Grazing. The Cape York properties' grazing practices fell mostly within the B and C categories (A=Best Practice) (Isha Segboer, SCYC, pers. comm., 2012).

An additional survey of 10 CYP properties (primarily Normanby catchment) conducted by DAFF placed the land management practices in the C and D category. However, this Framework was developed in southern GBR catchments and is not appropriate for the CYP grazing industry where properties are much bigger and less developed, which can be both good and bad for land condition and water quality (Joe Rolfe, DAFF, pers. comm., September 2012).

Many of the Normanby cattle stations are only marginally productive and there is very little capital available for long-term property management or soil conservation actions. Targeted government investment is needed to assist grazing land managers to reduce their impacts on wetlands and rivers via fencing (via appropriate methods, locations, and distances from waterbodies) and alternative water sources (also at appropriate distances and locations away from the rivers and erodible soils). For priority erosion 'hot spots' (where gullying into sodic or dispersible soils occur) the best solution is to spell or permanently exclude cattle from large areas of river frontage to avoid or reduce rates of gully erosion. Management recommendations are discussed in Section 6 and priority actions are listed in Table 8. Shellberg and Brooks (2013) also review in detail grazing impacts and management options on highly erodible soils in the Normanby catchment to prevent or reduce gully erosion.

## 5.2 Horticulture

**Figure 12: Sediment laden water run-off from a recently cleared banana farm (December 2011)**

Horticulture in the Normanby catchment is mostly limited to the rich basaltic soils around Lakeland Downs on the upper reaches of the Laura River, and is estimated to cover 35 km$^2$ or 0.1% of the Normanby catchment (Reef Report Card 2009); however this area has been expanding.

Impacts on the Environmental Values of the Laura River from horticulture include:

- **Increased nutrient levels and associated algal growth** impacting on the quality of aquatic habitat, cultural values & stock water;
- **Low levels of herbicides & pesticides** are not likely to impact on aquatic health, but potentially could be accumulating in fish and impacting recreational and cultural fishing values;
- **Increased sediment run-off** as a result of soil tillage (Figure 12);
- **Reduced downstream water flows** due to over-extraction of groundwater and surface water, and surface water impoundments.

Water quality impacts on the downstream Environmental Values of Lakefield National Park or Princess Charlotte Bay have not been documented. However, the rivers, springs, wetlands and groundwater of the Normanby catchment are intricately connected. Over-extraction of groundwater or surface water for irrigation may reduce downstream baseflows in the Laura River and wetlands fed by groundwater springs in Rinyirru (Lakefield) National Park.

Many of the tributaries to the Normanby, including the Laura, are dependent on groundwater springs to provide flow during the dry season. Over-extraction of groundwater has the potential to reduce or halt surface water flow during the dry season. According to a CSIRO report, the risk of impact from development on the dry-season flow of these rivers is high (CSIRO 2009).

Surveys of 7 horticultural growers in the Normanby were conducted by CYSF as part of Reef Rescue. According to the Great Barrier Reef First Report Card (2009 Baseline), cutting-edge or best management (B) practices for nutrients are used by 53 per cent of the producers surveyed. Nutrient management practices considered unacceptable by industry and community standards are used by 20 per cent of producers. Cutting-edge or best management practices for herbicides are used by 89 per cent of producers, while four per cent of producers are using unacceptable herbicide management practices.

Improvements undertaken by local banana farmers (assisted by Reef Rescue funding) include the use of compost to reduce fertilizer use by 50%. Additional management actions to reduce the levels of nutrient and sediment run-off are required to improve water quality in the Laura River.

Management recommendations are discussed in Section 6 and priority actions are listed in Table 9.

## 5.3 Road and Track Erosion

Road erosion has been identified as a major source of elevated sediment loads in the Normanby catchment, degrading the water quality of surrounding streams and rivers (Gleeson 2012, Brooks et al 2013). Studies have shown that unsealed roads can be a greater source of sediments than agricultural land use (Motha et al. 2004).

A conservative estimate of the total surface area of the Normanby catchment main unsealed road network is 56.76 $km^2$. This area is greater than the total area used for intensive agriculture and does not include many small, unsealed roads, tracks and fence lines on lease and private properties (Gleeson 2012). The main unsealed road network of the Normanby catchment has been estimated to intersect at least 1,300 times with the mapped steam and river network (Gleeson 2012), with each of these connections forming a direct pathway for sediment derived from the roads to be delivered to the watercourse. Many more stream connections than this occur with drainage lines that fall below the threshold for mapped streams, or with smaller unmapped roads, tracks and fence lines.

The discharge of suspended sediments from newly constructed unsealed roads decreases over time after initial erosion, However in the Normanby catchment, the roads are re-graded every year after the wet season rains have damaged the unsealed road network. Annual re-grading results in a new supply of sediment being available every year to be discharged into surrounding streams and rivers (Gleeson, 2012).

In addition to the road surface derived sediment run-off, unsealed roads also cause gully erosion. Measurements of the frequency and magnitude of road induced gullies (Gleeson 2012) indicate that there is potentially around 1800 $m^3$ of gully erosion per km of main unsealed road that could be contributing to elevated sediment loads within the Normanby stream network (Brooks et al., 2013).

Smaller roads, tracks, and fence lines on lease and private properties also can have significant erosion and sediment run-off. For example, Shellberg and Brooks (2013) measured 240 to 660 tonnes/km/year (900 to 1600 tonnes/ha/year) eroding off station dirt roads on steep banks in the upper Normanby, which is very high on a world scale. This does not include the adjacent gully erosion caused by station roads. Recommendations for improved practices for the construction and maintenance of roads and fences on dispersible or sodic soils in the Normanby catchment have been summarized by Shellberg and Brooks (2013). This includes avoiding accelerated erosion associated with riparian fencing funded by Reef Rescue with the goal of reducing the sediment supply to the Normanby River.

Management recommendations for roads and fences are discussed in Section 6 and priority actions are listed in Table 10.

### 5.5 Fire

Fire is a natural component of savannah landscapes as well as a resource management tool used by indigenous and European Australians. Burning methods vary depending upon the objective, which can include protecting biodiversity, weed control, pasture management, controlling woodland thickening and reducing wildfire hazard. Inappropriate burning or wildfires in the catchment can increase erosion and have a significant effect on water quality and HEV aquatic ecosystems. River frontage areas with highly- erodible sodic soils are particularly vulnerable to the effects of fire (Shellberg and Brooks 2013).

### 5.3.1 Fire and Water Quality

The impacts of fire on water quality depend upon: the frequency, intensity and extent of burning; rainfall patterns; catchment characteristics such as slope, ground-cover, vegetation type and soil type; and the time interval between burning and subsequent runoff (Townsend and Douglas 2000).

By removing ground cover and soil organic matter, fire can lead to increased water runoff rates and the initiation or acceleration of erosion. Early-dry season (low intensity) fires tend to burn less area and do not remove all ground cover, while late-dry season (high intensity) fires reduce canopy cover and remove most ground cover. A longer time period between burning and rainfall allows for more re-growth prior to the wet season, and therefore a reduced risk of erosion. Research in Northern Australia has shown that late dry season fires result in greater run-off of sediments and increased nitrogen, phosphorous, and suspended sediment concentrations in adjacent waters compared to early dry season burns (Townsend and Douglas, 2000). Sediment loads measured from catchments with an early dry season burning regime were approximately half those from adjacent catchments with a late dry season fire regime (Townsend et al. 2004).

Fire temperature and vegetation type are significant factors in the release of nutrients into adjacent waters. High intensity fires release ammonium and particulate phosphorous into the atmosphere (Qian Y Fau-Miao *et al.* 2009) and the aerial deposition of smoke and ash can result in increased phosphorous and nitrogen levels in streams (Spencer et al., 2003, Townsend and Douglas, 2000). The deposition of ash can reduce dissolved oxygen levels in adjacent rivers, which has resulted in fish kills in the ACT and Northern Territory (Waterwatch Campfire Report 2004; Andrew Hartwig, pers. comm., 2012).

Although the impacts of fires on water quality in the Normanby River have not been well documented, statistical analysis of water quality data and fire history maps has shown a significant positive correlation ($p<0.01$) between the total area burnt within a sub-catchment of the Normanby over a given year and mean annual turbidity, ammonia and nitrogen oxide levels at water monitoring sites within the sub-catchment. There was a strong negative correlation between the area of a sub-catchment burnt and wet season concentrations of dissolved oxygen. While not conclusive, these results indicate that oxygen levels dropped in response to fires and turbidity and dissolved nitrogen levels increased (Howley, unpublished data).

### 5.3.2 Fire Frequency and Late Dry Season (High Intensity) Burns

Traditional Owners and other land managers are concerned about the frequency of late dry season fires in the Normanby catchment (tkrp.com.au). Fire history maps show that more than 85% of the catchment has experienced at least 2 late burns within the past 12 years and more than 45% of the catchment has burnt late 4 or more times in that period (NAFI 2013a). The most frequent late burns occur in the lower catchment on the east side of the Normanby River (Kalpowar region) and in the Morehead and Hann River catchments (Figure 13). (*Late burns are defined by NAFI as fires occurring between August- December; these percentages may include prescribed storm burns*).

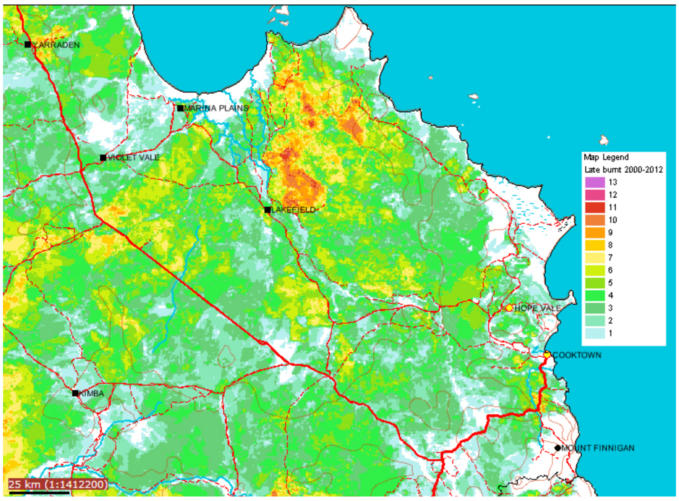


**Figure 13: Frequency (number of years) of late dry season burns in the Normanby catchment between 2000 – 2012 (NAFI 2013a)**

Areas highly susceptible to erosion such as river frontage areas with sodic soils prone to alluvial gully erosion should be burnt very infrequently or never (Shellberg and Brooks 2013). Anderson et al. (1988) recommended patch-burning areas susceptible to erosion with low intensity fires no more than every 3 years either in the early-wet season or early-dry season. Over the past 12 years, at least 40% of the catchment has been burnt more than every three years (NAFI 2013b).

### 5.3.3 Early Dry-Season (Low Intensity) Fires

Early-dry season (low-intensity) fire (May-July) can be used to reduce the occurrence and area of high intensity late-dry season fires. Patch burns or mosaic burning should be rotated across the landscape and different vegetation communities (leaving ~30% un-burnt) so that any given area is only burnt every 2 to 5 years early in the dry season  (Reef Catchments 2011a). It is important that the same areas are not burnt every year, otherwise annual grasses can replace preferred perennial grasses (Gabriel Crowley, pers. comm., July 2013). Episodic low intensity fires can leave behind unburnt grass, organic mulch, and re-growth that can protect the soil surface from rains at the end of the dry season (Anderson et al. 1988). However, cattle grazing of perennial grass re-growth following fires needs to be carefully managed to protect grass vigor during early growth periods. The timing of early-dry season burns also needs to be carefully selected to avoid interrupting the native grass seed cycle before seeds have matured, or prematurely burning actively growing perennial plants.

### 5.3.4 Storm burns

Overgrazing, lack of fire, and/or frequent early-dry season burning have led to the invasion of woody species such as broad–leaved paperbark (*Melaleuca viridflora)* into swampy grasslands, including the marine plains at Princess

Charlotte Bay (Crowley et. al 2009, Crowley and Trueman 2005, Stanton 1995). "Storm burns" in the early-wet season (fires lit 2-3 days after the first heavy rain >25mm) are used to kill seedlings and suckers and prevent woodland thickening of grasslands or grassy woodland (Reef Catchments 2011a, Crowley et. al 2009). However, if left too long after the first rains, storm burns can be difficult to control, reduce grass cover, increase soil erosion during subsequent rains, and reduce the health of perennial grass early in their growth cycle. Cattle grazing of perennial grass re-growth also needs to be carefully managed to protect grass vigor.

While storm burns are an important management tool for specific vegetation communities of the Normanby catchment (i.e., swampy grasslands with *Melaleuca viridflora*), they are not appropriate for all vegetation communities or soil types. They should be conducted with extreme caution along river frontages with dispersible or sodic soils, due to potential to expose erodible soils during early-wet season rainfall (Shellberg and Brooks 2013). Along river frontage they should only be used in small controlled patches where long-term improvements of grass cover can be demonstrated to reduce gully erosion.

If major woodland thickening or invasion of rubber vine (*Cryptostegia grandiflora*) has occurred along specific locations of erodible river terrace or floodplain, tailored storm burns and cattle spelling regimes could be used as a restoration tool at local patches to reduce tree/shrub cover and increase perennial grass cover (Orr et al. 1991; 1997; 2001; Orr and Paton 1997; Orr et al.; Orr 2004; Crowley and Trueman 2005; Drucker et al. 2008; Crowley et al. 2009). Good perennial grass cover is essential for reducing soil erosion in the long-term.

### 5.3.5 Riparian Vegetation and other HEV aquatic ecosystems

It is not recommended to burn vegetation fringing watercourses unless for specific management outcomes (Reef Catchments 2011b). Riparian and wetland vegetation is fire sensitive and damage can result from even low intensity fires (Reef Catchments 2011a). Riparian vegetation diversity and density decreases significantly in burnt areas compared to unburnt areas, with the greatest loss of vegetation in catchments burnt late in the dry season (Anderson et al. 2005). Loss of native riparian vegetation can affect stream bank stability, gully erosion potential, and allow weed species to establish (Horn 1995). Early-dry season back burns in surrounding fire prone vegetation can help protect riparian vegetation from higher intensity fires (Reef Catchments 2011a).

High intensity (late dry season) fires have been used to successfully control rubbervine (a highly invasive weed) in some riparian HEV areas (Stanton, 1995). However, intense fires can destroy sensitive vegetation types and still not kill large established rubbervine plants. Storm burns may be more effective at killing established rubbervine plants. Where high intensity fires are necessary in riparian areas, early dry season burns should be used to create firebreaks and keep hot fires contained along small (2-3 km) stretches of the river (Mick Blackman, pers.comm., July 2013). Areas with high gully erosion potential (sodic soils) should be avoided to reduce accelerated erosion at the beginning of the wet season. However, if perennial grass and riparian cover can be improved, it may reduce erosion in the longer term. Erosion and water quality impacts must be carefully balanced with any fire regime.

**Figure 14**: Evidence of high intensity fire in riparian paperbark forest on the Kennedy River, Rinyirru National Park (Photo: C. Howley, April 2013)

The perched swamps on the Laura sandstone could be sensitive to hot fires, particularly as they are noted to contain a peat layer which can be difficult to extinguish once lit. Until more is known about the ecology of these perched swamps and management recommendations formed, prescribed burns should be used cautiously and destructive intense fires prevented.

### 5.3.6 Fire Management Recommendations

Balancing the needs of riparian vegetation, perennial grass cover, weed control, fire management, erosion control, and cattle grazing is complex and needs further research – particularly on river frontage country prone to gully erosion (Shellberg and Brooks 2013). **The water quality impacts of any fire regime should be carefully considered.** Recommendations for managing fire to reduce erosion and protect perennial grass and riparian vegetation in the Normanby catchment are discussed in Section 6 and Table 11.

## 5.4 Feral animals – Pigs, Cattle, Horses

Environmental values including aquatic ecosystems, cultural values, irrigation, livestock water and commercial and recreational fishing can all be affected by the impacts of feral animals, including pigs, horses and cattle.

During the dry season, feral pigs disturb sediments and destroy aquatic vegetation cover in the majority of wetlands within the Normanby catchment, significantly increasing suspended sediment and nutrient levels. During the wet season, these sediments and nutrients are flushed into the Normanby River, potentially increasing sediment loads in the River and discharging to Princess Charlotte Bay.

Feral pigs are one of the major threats to the ecological condition of HEV wetlands including Jack Lakes, the Laura Sandstone springs, Violet Vale, Rinyirru (Lakefield) and Lama Lama National Parks. The disturbance of sediments and destruction of aquatic plants by feral pigs at Rinyirru NP wetlands has been shown to increase turbidity and nutrient levels and reduce oxygen levels and pH compared to wetlands with pig-exclusion fences (Doupe et al. 2008). High turbidity (> 800 NTU) and nutrient levels exceeding ANZECC water quality guidelines for wetlands have been recorded during the dry season at Jack Lakes as a result of both pigs and cattle stirring up sediments within the wetlands (Stephan & Howley 2009). The physical disturbance of acid-sulphate soils (present at Jack Lakes and Rinyirru wetlands) may impact water quality by reducing pH and releasing metals into the water column. Changes in wetlands vegetation and water quality degrades fish habitat and could decrease fish populations or alter species composition.

On-going aerial culling efforts have significantly reduced the presence of pigs and observed impacts on wetlands within Rinyirru National Park (Jim Mitchell and Andrew Hartwig, pers. comm., July 2013).

Feral cattle and horses have also become established in Rinyirru Lakefield National Park over the years. Horses and cattle spread weeds, destroy riparian vegetation, and increase suspended sediment concentrations in waterways. They also compete with wildlife for water and food (Howley & Stephan 2005).

Priority Management Actions for feral animals are listed in Section 6 Table 13.

## 5.5 Aquatic & Riparian Weeds

The spread of exotic weeds and resulting loss of native plants is the most widespread form of land degradation in the Normanby catchment. Weeds directly and indirectly impact on water quality and HEV areas. Aquatic weeds such as hymenachne (*Hymenachne amplexicaulis)* and salvinia (*Salvinia molesta*) invade watercourses and smother native aquatic plants, alter stream flow and deoxygenate water. Rubbervine (*Cryptostegia grandiflora*), sicklepod (*Senna obtusifolia*) and numerous (undeclared) weeds such as *Hyptis suaveolens* invade riparian zones and river benches, choking out native trees and grasses.

Once established, weeds can benefit from disturbances such as over grazing perennial grass and inappropriate fire regimes, often outcompeting native grasses. Compared to the deep rooted native perennial grasses that they replace, many annual weeds provide little ground cover early in the wet season, have low root density and soil cohesion, and change the infiltration potential of soils. Thus weed invasion could promote accelerated water runoff from floodplain and terrace flats, reduce soil cohesion on steep river banks and hollows, and contribute to the initiation or acceleration of alluvial gully erosion (Shellberg and Brooks, 2013).

Following is a brief overview of the impacts of specific weeds on water quality and Normanby River Environmental Values. Priority Management Actions for weeds are listed in Section 6 Table 13.

### 5.5.1 Hymenachne (*Hymenachne amplexicaulis)*

Hymenachne was originally introduced to Australia to provide ponded pasture for cattle, and has been listed as one of 20 Weeds of National Significance (WONS) because of its ability to invade and destroy natural wetlands, as well as degrade wetlands that act as nursery areas for commercially valuable fish such as barramundi (ARMCANZ, 2000).

Hymenachne forms pure stands that exclude native plant species and dependent wildlife. During dry periods Hymenachne contributes large loads of organic matter to the water body. This material decomposes and consumes available oxygen. The anoxic conditions that can be created beneath floating mats of Hymenachne can facilitate the release of nutrients such as phosphorus from sediments, which provides a supply of nutrients for the weed (DNRMW, 2006). Dense Hymenachne mats can modify water flow and watercourses (DAFF, 2012) and prevent the infiltration of sunlight through the water column. This limits or prevents photosynthesis and oxygen production by submerged aquatic plants, which threatens fish habitats and nursery areas (DNRMW 2006).

Hymenachne was found in Rinyirru (Lakefield) National Park in February 2011, and is currently present in 11 isolated wetlands covering an approximate area of 20 ha, including the iconic Red Lily Lagoon. The infestations in the National Park are restricted to wetlands and low-lying areas on the floodplain between the Normanby and Kennedy Rivers; however the risk of spread to all major watercourses, wetlands, floodplains and low-lying areas on Rinyirru is extremely high due to the interconnectivity of all the wetland systems on the park. This incursion has been flagged by DEEDI, CSIRO and the National WONS coordinator for Hymenachne as a priority for eradication due to the potential detrimental effects on Rinyirru's high value aquatic ecosystems (Still, 2012).

Upper catchment gully erosion and elevated sediment loads (Brooks et al. 2013, Shellberg and Brooks 2013) may assist Hymenachne establishment throughout Rinyirru (Lakefield) National Park with the additional sediment settling and forming banks ideal for propagation. Feral pigs add to the problem by rooting and wallowing in the soft banks and spreading viable stem fragments. Hymenachne has not been documented at other High Value Aquatic Ecosystems within the catchment; however it is present on other properties and is easily spread by water, feral animals and birds.

### 5.5.2 Sicklepod (*Senna obtusifolia*)

Sicklepod is a vigorously growing, very competitive woody shrub that can invade pastures, roadsides, fence lines, and especially creek and river banks and benches. It can completely dominate pastures and riparian zones within two to three growing seasons (Mitchell and Hardwick 1995).

Sicklepod is currently one of the most rapidly spreading weeds in the catchment. It has formed monocultures in riparian areas along many stretches of the Normanby River and its tributaries (East/West Normanby, Laura, Morehead Rivers, etc.). The widespread invasion of sicklepod (*Senna obtusifolia*) onto river benches and inset floodplains has had an unknown effect on alluvial gully initiation and acceleration (Shellberg and Brooks 2013). Sicklepod invades open patches in riparian zones that were previously occupied by native herbs, shrubs and grassland pockets. The transformation of perennial grass or native plant communities to sicklepod monocultures may destabilise river benches and banks and increase erosion. According to Creel et al. (1968), sicklepod contains a non-persistent phytotoxic substance that could inhibit the germination of other plant seed and possibly further disadvantage native ecosystems from regenerating.

The control of sicklepod is a major challenge in part due to its long seed life, over a decade (Mackey et al. 1997; QDEEDI 2011). Herbicide spraying and burning are fairly ineffective over large scales, but some advances in biological control remain promising (Mackey et al. 1997; Palmer 2012). Further investigation is needed into the impacts of large scale monocultures of sicklepod on water quality and HEV systems, and the appropriate management responses in riparian areas.

### 5.5.3 Rubbervine (*Cryptostegia grandiflora*)

Rubbervine was previously described as the most potentially devastating weed on Cape York Peninsula due to its ability to invade entire river systems (Mitchell and Hardwick 1995). However, sicklepod (*Senna obtusifolia*) is more recently rapidly achieving this role. Regardless, rubber vine can smother and kill riparian vegetation and large trees and form dense, sometimes impenetrable thickets. This decreases biodiversity, alters stock and native animal access to water, and harbours feral animals. Rubber vine is toxic to stock and can leach toxic compounds into streams (Ryan et al. 2002). Dense thickets of rubber vine can effectively shade out understory grasses along steep banks and river benches, leaving alluvial soils bare underneath, making them more vulnerable to gully erosion (Shellberg 2011).

Rinyirru (Lakefield) National Park has rubbervine infestations along the Normanby, Laura and Annie Rivers as well as minor creeks such as Two Mile Creek (Still 2012). Through the introduction of Rubbervine rust (*Maravalia cryptostegiae*) and regular fire management, rubbervine has shrunk in total range in the past 10 years. The successful treatment has in part been due to the removal of (most) cattle allowing for increasing ground cover to carry a hot fire needed to kill rubbervine (Stanton 1995). However, intense fires are not recommended for controlling rubbervine adjacent to rainforest or riparian zones as the heat can destroy sensitive vegetation types and still not kill large established rubbervine plants. A low intensity burn through these areas, when there is moisture in the soil to allow for natural regeneration, is enough to kill young rubbervine suckers without destroying established native plants. Larger individuals will need to be injected with herbicide (Andrew Houley, Reef Catchments, pers.comm., July 2013).

Rubbervine remains widespread outside of the National Park along the Little Laura River, and the Laura River at 'Crocodile', 'Olive Vale', 'Fairview', and 'Springvale' Stations (Shane Forester, CYWFAP, pers. comm., June 2013). These infestations outside of the park appear to be increasing, and given that they are towards the top of the catchment represent a significant threat to much of the river network downstream. As such, the infestations in these areas should be a priority for eradication while they are still at a manageable scale.

### 5.5.4 Salvinia (*Salvinia molesta*)

Salvinia is a declared Weed of National Significance because of its severe impact on freshwater ecosystems (ARMCANZ 2000). Floating mats of salvinia prevent light entering the water body and reaching submerged plants. Masses of decaying salvinia can de-oxygenate the waters on which they are growing, resulting in the death of fish and other aquatic fauna. Infestations also increase the rate of water loss, because the plants use water faster than it evaporates (DEPI 2011).

Lakeland's Perfume Gully was the first known area of Salvinia on Cape York Peninsula. From here Salvinia spread to Honey Dam, Bullhead Creek and the Laura River 25km downstream at Carrolls Crossing. Prior to control works, Salvinia was a significant threat to the aquatic ecosystems of Rinyirru National Park (40 km downstream) as the small plants can be difficult to observe and exclude native species. High nutrient conditions in the Lakeland Downs area supported the growth of Salvinia and may have contributed to the Salvinia outbreak (Howley & Stephan 2005).

Salvinia appears to have been eradicated from the system in recent years due to the introduction of the biological control agent – *Cyrtobagus* weevil – and major removal efforts by local community groups. As from July 2013, no Salvinia has been found in the system for over 2 years (Jason Carroll, SCYC, pers. comm., July 2013).

## 5.6 Mining/ Coal & Minerals

Most of the mines in the Normanby catchment are abandoned gold mines previously operating in the upper reaches of the Normanby and Laura Rivers (DEEDI 2010). However, exploration permits for both minerals and coal have been issued for large areas of the catchment, particularly in the upper Laura and Normanby rivers and at the Bathurst Range near Princess Charlotte Bay (Figure 15; Figure 16). Exploration for diamonds has also progressed in the upper catchment area surrounding Lakeland Downs. High grades of alluvial gold and significant platinum and palladium contents occur in the Laura River (Howley & Stephan 2006), and a large coking coal deposit exists at the Bathurst Range.

An underground coal mine has been proposed to extract the resources at Bathurst Heads (Figure 16). The mining area is located within the Normanby catchment. The proposal includes the development of a port at Bathurst Bay to transport the coal, and all weather road access to the site, which would involve major road infrastructure development through the Normanby catchment.

The proposed mine at Bathurst Range has the potential to impact on groundwater and surface water resources of eastern Princess Charlotte Bay and the Marrett River. In addition to specific impacts on water quality and quantity from mining activities, potential impacts from mine associated road upgrades include the spread of weeds and increased degradation and fishing pressure from year round access to Rinyirru National Park and Bathurst Heads. Potential impacts on PCB waters, seagrass meadows and corals reefs from increased shipping include increased turbidity from the disturbance and re-suspension of shallow sediments, oil spills, and vessel strikes; however the proposed shipping frequency is low (approximately 1 ship per month).

Mine exploration in the upper catchment poses significant threats to both the cultural and aquatic values of the HEV and HCV ecosystems of the Laura Sandstone springs and Laura, Little Laura and Mosman Rivers. The extraction of groundwater often associated with mining could reduce water flows at groundwater springs at the Laura Sandstone and downstream groundwater dependent ecosystems. Earthworks, including the development of roads in areas of highly erodible soils (Figure 17; Figure 18) have a high potential to increase erosion and suspended sediment levels in the Laura or Normanby Rivers.

Management Actions for Mining & Exploration are listed in Table 12 Section 6.

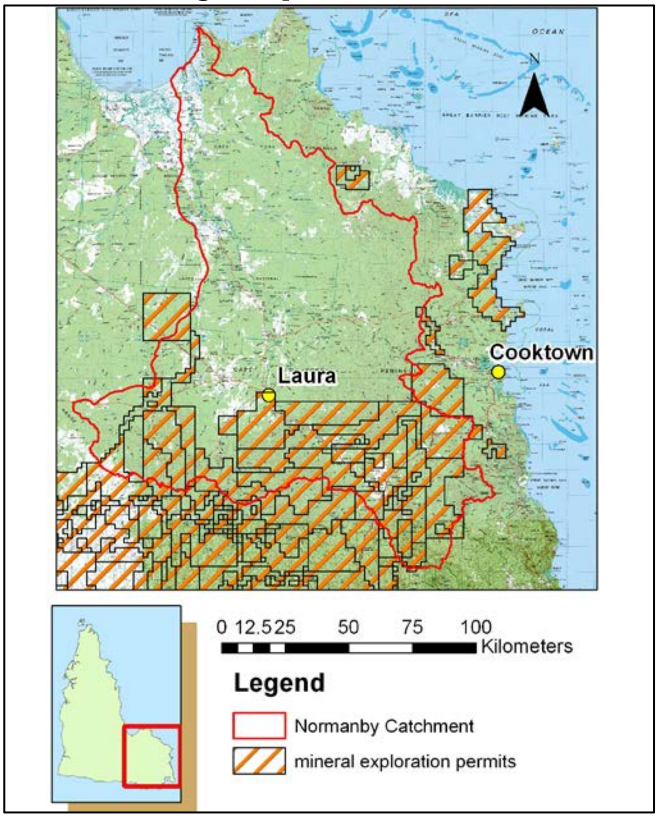


**Figure 15: Current Mineral Exploration permit applications in the Normanby Catchment (Qld DNRM 2012)**

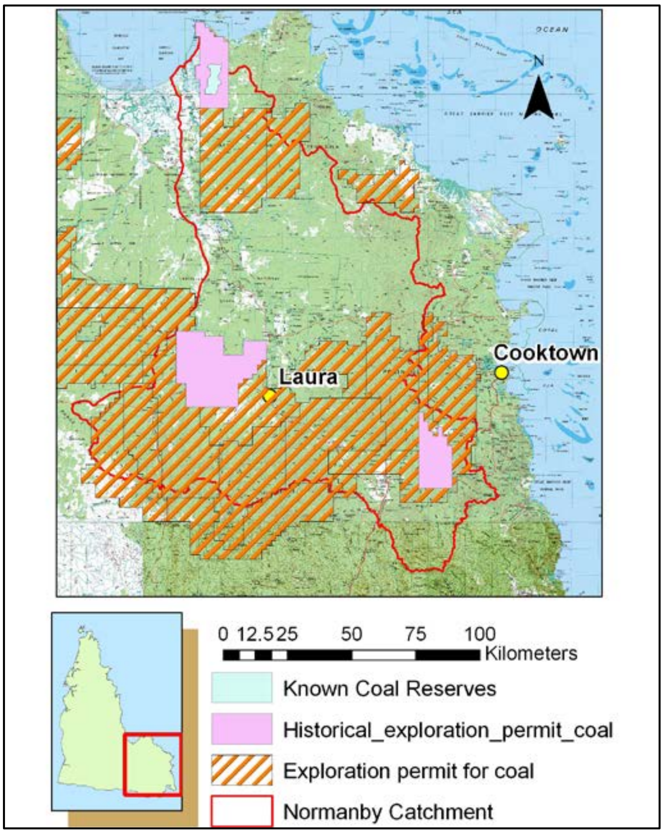


**Figure 16: Current and Historic Coal Exploration Permits and Known Coal Reserves in the Normanby Catchment (Qld DNRM 2012)**

# 6 MANAGEMENT ACTIONS FOR WATER QUALITY BENEFITS

The priority pollutants of concern for the Normanby catchment are sediments and nutrients. Herbicides have been detected in the Laura River, its tributaries, and Princess Charlotte Bay but not at levels of high concern. However, increased agricultural development in Lakeland and along the East and West Normanby Rivers could change this in the future, especially coupled with increased water withdrawals during base flow. Management Recommendations for reducing sediment and nutrient loads are discussed in the following sections. Additional Research and Monitoring is crucial to better understand pollutant sources and Best Management Practices (BMPs) for the Normanby catchment.

## 6.1 Suspended Sediments: Erosion Prevention and Rehabilitation

Gully erosion and bank erosion are the major sources of sediment in the Normanby catchment and have been accelerated by land use impacts (Brooks et al. 2013; Shellberg and Brooks 2013). To successfully reduce sediment loads in the Normanby River and its tributaries, large-scale, long-term management actions are needed to address a range of land use issues that are contributing to increased gully and bank erosion. These issues include grazing management of grass cover, cattle tracks and other soil disturbance along "river frontage" country (including river banks, floodplains, terraces), weed invasion, altered fire regimes, and road and fence design and maintenance.

Concentrated areas of alluvial gully erosion and soils with high erosion risk have been identified for the catchment (Figure 9; Figure 17). Specifically, large river frontage paddocks on four main cattle properties in the upper catchment contain the bulk of the eroding gullies, and these frontage paddocks are where cattle tend to congregate. These are the priority areas (Figure 17) for investments in erosion reduction measures using large-scale land management changes and localised intensive rehabilitation actions to reduce sediment yields to downstream rivers, wetlands, estuaries, coasts, and off-shore reefs.

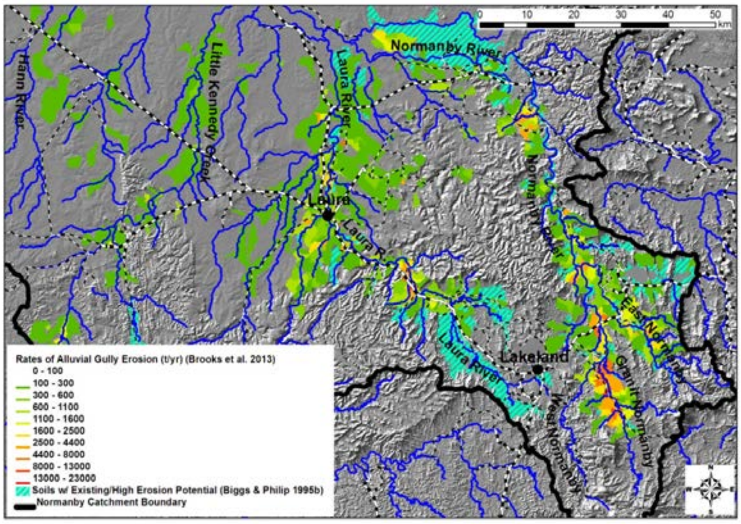


**Figure 17: Erosion "Hotspots" in the upper catchment (red and orange = areas with the highest rates of erosion, turquoise = highly erodible soils)**

In addition to these concentrated "hot spots" of gully erosion, erosion from widespread road, fence, feral pigs and stream bank sources can have significant impacts on HEV or HCV aquatic ecosystems. Therefore to reduce total sediment loads, improved management practices need to be adopted across the Normanby catchment, particularly in areas of existing erosion or erosion prone soils (Figure 18). Targeted rehabilitation actions will also be appropriate at specific HEV sites outside of the mapped hot spots for erosion. Roads and fences can be addressed by improved design and maintenance practices. Erosion from small stream banks needs to be addressed through improved management of grass cover to reduce water runoff and increase bank stability. Fire can be used at appropriate locations, times and frequency across the catchment to protect and improve grass cover in erosion sensitive areas by the end of the dry season. Culling and exclusion fences will reduce feral animal impacts on HEV wetlands.

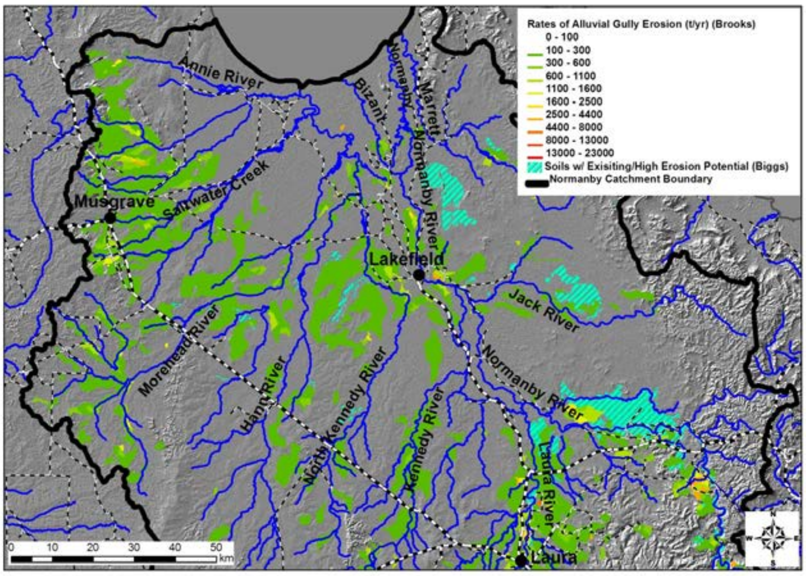


**Figure 18: Erosion "Hotspots" in the lower catchment (red and orange = areas with the highest rates of erosion, green= moderate rate of erosion, turquoise = highly erodible soils)**

Detailed property planning is needed with multidisciplinary contributions, as well as rigorous monitoring to document the water quality and economic outcomes from altered land management practices. Specific erosion prevention and rehabilitation practices are detailed in Shellberg and Brooks (2013).

Recommendations for sediment loads by reducing gully erosion along river frontage areas are discussed below. Additional priority actions are listed in Management Action Tables 8 - 13.

### 6.1.1 Grazing Land Management on Highly Erodible Soils

Improved grazing land management (GLM) practices to reduce erosion are required to prevent or reduce water quality impacts in the Normanby catchment, particularly on the mapped areas of highly erodible soils. Large scale prevention of gully erosion is more efficient and cost effective than rehabilitating gullies. Management techniques that promote perennial grass cover, prevent gully initiation, and promote gully rehabilitation include cattle exclusion from highly erodible soils, seasonal spelling of river frontage areas, reduced grazing pressure to increase vegetation cover, and off-stream water points on stable geology.

***Cattle Exclusion from Erodible River Frontage Country***

Permanent cattle exclusion is needed around areas of concentrated gully erosion and highly erodible sodic soils (Figure 17) to allow for vegetation recovery and to reduce further damage to soils from hoofs and cattle pads. The creation of 'soil conservation areas' would set aside the most highly degraded land in the catchment and provide an opportunity to monitor the long-term water quality benefits from improved land management practices (cattle management, fire changes, weed control). This may be achieved through payments for ecosystem services (carbon, biodiversity, soil retention) for landholders to destock or manage cattle in sensitive high risk areas, or by purchasing priority land areas for long-term conservation.

Based on detailed erosion research conducted in the Normanby catchment (Brooks et al. 2013; Shellberg and Brooks 2013), the highest priority site for the purchase of active grazing land for cattle exclusion and erosion reduction purposes is located in the Granite Normanby catchment (Appendix C).

***Cattle Rotation and Seasonal Spelling***

Outside of the highest priority erosion zones, or where exclusion is not an option, wet season spelling of cattle should be promoted to improve perennial pasture health and reduce erosion. Wet season spelling can occur annually or every few years to benefit perennial grass species (3P species) during their growth and seed cycles and target weed species at critical times to reduce competition or prevent seed set. Landholder compensation or stewardship payments may be necessary in addition to working with land managers to assess the long-term economic and environmental gains of spelling.

***Off-stream Water Point Development***

Artificial off-stream water points for cattle (with or without fencing of riparian areas and adjacent floodplain flats) should continue to be an investment priority but on its own will not achieve sediment reduction goals. If improperly located and managed, off-stream water points can increase local grazing pressure on erosion prone soils. Water points should be installed on stable soils and geology outside of mapped erodible sodic soils and well away from river banks.

***Reducing Stock During Drought Periods***

Decreasing stock numbers early when summer rains are predicted to be below average will prevent over-grazing, save drought-induced cattle losses, reduce expenses such as feeding supplements, and preempt low economic returns from market fluctuations. Extension programs to advise landholders on the use of climate forecasts and to assess the economic and environmental benefits of reducing stock before critical events should be a priority.

***Ground Cover Targets***

Ground Cover targets are discussed in Section 7.2 and Table 21. Vegetation cover and other associated metrics should be regularly monitored at fixed plot locations on highly erodible 'river frontage' paddocks and riparian zones subject to cattle grazing (see Shellberg and Brooks 2013 for monitoring details).

### 6.1.2 Fire Management

The impacts of various fire regimes on water quality, riparian vegetation, perennial grass cover, weed control and erosion are complex and need further research. This is particularly the case on soils prone to gully erosion adjacent to rivers and creeks (Shellberg and Brooks, 2013). Nevertheless, **fire can be an important management tool for preventing and reducing erosion and the recommended investments in large-scale, long-term land management change should consider the appropriate fire regimes.**

For reducing erosion at the priority "erosion hot spots" (Figure 9; Figure 17) and on other areas of highly erodible soils adjacent to rivers and on elevated floodplains (Figure 18) fire regimes need to be tailored toward maximizing the health of perennial grass cover and minimizing weed dominance or spread. Projects aimed at reducing erosion and protecting perennial grass and riparian vegetation in the Normanby catchment should consider the following:

- Areas highly susceptible to erosion should not be regularly burnt under any regime to promote vegetative cover.
- Reduce the frequency of late-dry season (high intensity) fires by using early-dry season prescribed burns and installing fire breaks.
- Cattle spelling during the wet season (Dec-April) may be necessary to build up fuel loads for appropriate fire regimes.
- Spelling cattle from recently burnt country will allow perennial grass to grow and recover during critical growth period and may reduce weeds
- Repeatedly grading fence lines for fire breaks will accelerate erosion. Instead use early-dry season aerial and/or ground burning to install large fire breaks at locations that change each year.
- Early-wet season 'storm-burns' (1-3 days after >25mm rain) should be used cautiously along areas with dispersible or sodic soils to avoid accelerated water runoff and soil erosion at the start of the wet season.

Where high intensity burns are used in riparian areas for control of weeds such as rubbervine, install fire breaks to contain riparian fires to small areas (2-3 km). Alternatively, manual and chemical weed treatments may be more appropriate in erosion sensitive areas, providing it can be demonstrated that there will be minimal contamination of waterways.

### 6.1.3 Road and Fence Construction and Maintenance

Improved road construction and maintenance should be a high priority for the Normanby catchment. This will require significant investment in property planning and roadwork for local landholders, and a commitment from Cook Shire Council and Main Roads to design and maintain roads to minimise both short- and long-term erosion. Road Best Management Practices should be reviewed in more detail and implemented, including:

- Locating roads away from highly erodible soils.
- Minimising river, creek and gully crossings.
- Reducing grass and tree clearing along the edge of roads to reduce erosion potential.
- Minimising the scale and size of new road works.
- Placement of more frequent water diversions structures and drains to minimize runoff concentration.
- Careful diversion and management of water run-off to avoiding causing additional gully erosion.
- Reducing the frequency or scale of annual re-grading of dirt roads that increase sediment erosion.

- Bitumen may be an appropriate means of avoiding annual re-grading of dirt roads, however the over-sizing and over-engineering of newly constructed roads can cause additional erosion.

A catchment wide assessment of road impacts on water quality and HEV aquatic ecosystems should be conducted to identify priority sites for upgrades or re-location of roads. High priority sites within Rinyirru National Park have already been identified by the National Park managers (Section 3.2.2.2).

### 6.1.4 Fence Construction and Maintenance

Cattle fence lines can concentrate water and accelerate gully erosion when improperly placed, constructed, or maintained, in addition to when they are graded as fire breaks, used as roads, and cut by cattle tracks (pads). Property planning, management, and maintenance assistance is needed for grazing land managers to prevent and reduce erosion along fence lines. Fence Best Management Practices should be reviewed in more detail and implemented, including:

- Locating fences away from highly erodible soils to minimise future erosion and prolong the life of the fence.
- Minimising river, creek and gully crossings.
- Avoiding soil disturbance.
- Minimizing tree clearing and grass grading.
- Using live trees as fence posts ("tree to tree") on steep banks and crossings.
- Installing water diversion banks to minimize runoff concentration.
- Using prescribed fire, slashing and/or herbicides for fire breaks and vegetation management, rather than repeatedly grading fence lines as fire breaks and road access.

### 6.1.5 Weed Management for Erosion Control

Many annual weeds compete with preferred native perennial grasses, provide little ground cover at the beginning of the wet season, have low root density and soil cohesion, and change the infiltration potential of soils. Therefore, controlling weeds is a necessary component of water and erosion management in the Normanby catchment.

The control of weeds in riparian zones and adjacent areas is a major challenge. Herbicide use over large areas and long lengths of river frontage can be cost prohibitive and could have negative impacts on water quality. Mechanical control of weeds can be effective, but requires either high manual labor inputs or use of machinery on already cleared land. Mechanical control by hand is only appropriate for some species along riparian zones. Larger scale mechanical treatments along un-cleared river frontages could promote soil disturbance and erosion. Biological control of Rubbervine has been modestly successful and remains promising for other invasive species such as sicklepod.

Over large scales, the combined use of fire and wet season spelling of cattle are the best tools to promote the health and vigor of native perennial grass and the suppression of weed growth on pastoral properties where disturbance tends to be highest. Depending on exact timing, intensity, species, and vegetation community, fires can be effective at promoting native grass germination, production and cover while suppressing some weeds. The success of fire as a tool to control or eradicate weeds can depend on the grazing pressure on perennial grasses. When rotating cattle between paddocks, extreme caution also is needed to not spread weed seeds consumed by cattle.

Field research into balancing weed management, fires and erosion along river frontage areas is a major priority.

### 6.1.6 Direct Rehabilitation of Gully Erosion

Intensive gully rehabilitation is appropriate at strategic gully sites where HEV or HCV aquatic ecosystems are directly impacted (key waterholes, biodiversity hot spots, and/or cultural sites), where strategic infrastructure is threatened (roads, fences, dams, buildings, yards, key riparian paddocks), or where young incipient gullies can be intercepted before becoming massive, irreversible sediment sources. Many examples of young gullies appropriate for intervention and direct rehabilitation are located along the Laura River upstream of Kennedy Creek.

Numerous bio-geo-engineering options are available for direct intervention and rehabilitation of gullies, however most have not been well tested for alluvial gullies in northern Australia. These options and preliminary BMPs for direct gully rehabilitation are detailed in Shellberg and Brooks (2013).

## 6.2 Nutrient Run-off Reduction

Elevated nutrient levels have been documented in the Laura River associated with fertiliser use in the Lakeland Downs region. The impacts on water quality are primarily limited to the Laura River, its tributary Bullhead Creek and Boggy Creek (West Normanby tributary). However, the areas under horticulture are expanding and may soon include larger areas adjacent to the East and West Normanby Rivers as well as further along the Laura River.

Efforts to reduce fertiliser and soil run-off are a priority to protect downstream HCV and HEV areas, and can also benefit land-owners by reducing the economic costs of fertilisers and soil loss. Assessing the areas contributing most to nutrient and soil loss will allow for targeted management improvements in the Lakeland region. More detailed nutrient and sediment budgeting is needed around Lakeland to target these sources.

Management systems that reduce or eliminate tillage and maximise soil cover (via crop residue retention and grassed inter-rows) can reduce soil loss. Controlled traffic and contour banks (in already cleared areas) can also reduce runoff and soil loss. The use of sediment traps or reservoirs or artificial wetlands may be appropriate in some locations.

Nutrient loads are most effectively reduced by reducing fertilizer inputs and surpluses (State of Qld, 2013). Some efforts to reduce fertilizer run-off have been undertaken in the Lakeland region, through the use of compost to replace fertilisers. The actual water quality benefits of these efforts have not been documented, as compost sorting areas and direct compost application could also have runoff and pollution effects. Property-scale monitoring of surface water run-off and groundwater should be a part of all projects aimed at reducing fertiliser (soil and herbicide) lost to the environment.

Land-managers have requested assistance in identifying the best ways to reduce water, nutrient and soil run-off. Experienced extension officers who can work with land-managers and monitor the effectiveness of altered practices are needed in the region.

Specific recommendations for horticultural land management, including water extraction and irrigation, are listed in Table 9.

## 6.3 Pesticides and Herbicides

Low concentrations of herbicides have been detected in the Laura River. These concentrations are not currently considered to threaten freshwater or coastal aquatic ecosystems or other Environmental Values. However, with expanding agriculture in the region, actions to avoid future increases in contaminant levels should be supported and monitored. Recommendations for the on-going monitoring of contaminants and investigations into the sources of pesticides detected in crabs and passive samplers at PCB are listed in Table 14.

## 6.4 Knowledge Gaps and Other Planning Requirements

Monitoring and additional research into the sources of pollutants (sediments, nutrients, herbicides), where they are being deposited within the river, estuarine, and marine system, and how best to minimize land-use impacts on water quality is vital to prioritise actions to protect water quality in the Normanby River and the Great Barrier Reef. These findings will also provide important information for understanding and managing other GBR catchments.

Priorities for Future Research or Monitoring are listed in Table 14.

## 6.5 Management Action Goals and Priority Action Tables

**TABLE 7: CULTURAL VALUES MANAGEMENT ACTION GOAL AND PRIORITY ACTIONS**

| | |
|---|---|
| MANAGEMENT ACTION GOAL 1<br>**CULTURAL VALUES** | **Cultural values associated with the Normanby River and Princess Charlotte Bay are documented & HCV areas are managed to protect water quality and aquatic habitat. Traditional Owners are involved in identifying & implementing management actions and monitoring projects at HCV areas.** |

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 1.1 | Document aquatic sites of high cultural value (HCV) and traditional protocols for use of these areas | Melsonby, Laura River, East/West Quinkin Country, Kings Plain, East/West/Granite Normanby, Lakefield. Others | **HIGH**<br>Ranger Groups & Aboriginal Land Trusts |
| 1.2 | Investigate Indigenous and Environmental Water Allocation for Laura River | Laura River | **HIGH**<br>Laura Rangers |
| 1.3 | On-going monitoring of water flow, sediments, nutrients and herbicides in the Laura River downstream from Lakeland and new agricultural developments | Laura River, West & East Normanby | **MEDIUM**<br>Laura rangers, SCYC |
| 1.4 | Monitoring of seagrass meadows, turtle and dugong populations in Princess Charlotte Bay | PCB/ GBR | **MEDIUM**<br>Lama Lama rangers |

## TABLE 8: CATTLE GRAZING MANAGEMENT ACTION GOAL AND PRIORITY ACTIONS

| | |
|---|---|
| MANAGEMENT ACTION GOAL 2<br>**CATTLE GRAZING** | **Reduce cattle impact on water quality: increase late-dry season groundcover in frontage country to 50-80%; reduce cattle access to erodible soils, river banks, streams and wetlands at erosion "hotspots", HEV and HCV sites** |

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 2.1 | Provide financial and advisory assistance to land managers for detailed grazing property planning and the implementation of integrated actions including the management of grazing pressure, fire and weeds in river frontage country and BMP fencing & road construction. | Priority grazing stations identified on erosion hotspot maps, newly acquired indigenous owned properties | **HIGH**<br>Reef Rescue,<br>NRM groups, landowners |
| 2.2 | Seasonally spell or permanently exclude cattle from river frontage country at priority erosion "hot spots". Fencing to be constructed according to BMPs. Monitor vegetation cover and water quality outcomes. | Priority grazing stations are identified on erosion hotspot maps | **HIGH**<br>NRM groups, landowners |
| 2.3 | Increase the number of extension officers with relevant expertise in soil conservation, grazing and horticultural land management. Advise land managers on soil conservation techniques and conduct grazing management workshops including the use of climate forecasting. | Catchment wide | **HIGH**<br>Reef Rescue, DAFF, NRM groups |
| 2.4 | Commence socio-economic analysis of current grazing land management compared with alternative practices to reduce sediment and nutrient pollution. | Catchment wide | **HIGH**<br>Reef Rescue, DAFF, relevant economists |
| 2.5 | Provide alternative watering points and fencing (as per BMPs) to exclude cattle from river frontage and wetlands. Monitor vegetation cover and water quality outcomes. | Catchment wide | **MEDIUM**<br>NRM groups, landowners |
| 2.6 | Remove feral cattle from National Park/ CYPAL lands | Rinyirru, Jack Lakes NP | **MEDIUM** QPWS |
| 2.7 | Reduce stock numbers prior to drought periods using climate forecasts. | Catchment wide | **MEDIUM** BOM |
| 2.8 | Provide support for the management and control of largely unmarketable cattle on newly acquired indigenous lands (former cattle stations) | Catchment wide | **MEDIUM**<br>DAFF |
| 2.9 | Develop appropriate, robust, and data rich ABCD or other Framework for assessing grazing and horticultural land condition and monitoring changes | Catchment wide | **LOW**<br>Reef Rescue, DAFF |

## TABLE 9: HORTICULTURE MANAGEMENT ACTION GOAL AND PRIORITY ACTIONS

| MANAGEMENT ACTION GOAL 3<br>**HORTICULTURE & IRRIGATION** | **Minimize sediment run-off and nutrient losses to groundwater and surface water; maintain environmental flows and water availability for multiple uses downstream from water extraction and impoundment areas.** |
|---|---|

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 3.1 | Increase the number of extension officers with relevant expertise in soil conservation and horticultural land management | Catchment wide- horticulture properties | **HIGH**<br>Reef Rescue, DAFF, NRM groups |
| 3.2 | Property based monitoring of water quality impacts to identify priority sites for investment and monitor outcomes from altered land management | Catchment wide- grazing & horticulture properties | **HIGH**<br>Reef Rescue, NRM groups |
| 3.3 | Provide assistance to landowners to identify and adopt improved management practices to reduce run-off of topsoil, losses of fertilisers to groundwater and surface water and minimize use of pesticides. | Downstream from Lakeland region (Laura River & Boggy Creek) and new developments on East & West Normanby | **HIGH**<br>Reef Rescue, NRM groups |
| 3.4 | Develop a Water Resource Plan for surface water and groundwater use in the Lakeland region based on a scientific assessment of water resources, current and future uses (stock water, irrigation, domestic) and environmental water flow requirements. | Laura River, East and West Normanby River- potential impact on downstream environmental and social water availability and water quality | **HIGH**<br>DNRM |
| 3.5 | On-going monitoring of water flow, sediments, nutrients and herbicides in the Laura River downstream from Lakeland and new agricultural developments | Laura River, West & East Normanby | **MEDIUM**<br>Laura rangers, SCYC, DNRM |
| 3.6 | Develop appropriate ABCD or other Framework for assessing horticultural land condition and monitoring changes in land-use and water quality. | Catchment wide- grazing properties | **LOW**<br>Reef Rescue, DAFF, landowners |

## TABLE 10: ROADS AND FENCES MANAGEMENT ACTION GOAL AND PRIORITY ACTIONS

| MANAGEMENT ACTION GOAL 4<br>**ROADS & FENCES** | **Reduce impact of roads and fences on water quality through improved construction and maintenance methods, and targeted rehabilitation actions at erosion hot spots and HEV sites.** |
|---|---|

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 4.1 | Conduct detailed review of road practices and develop draft BMP guidelines for main road and track construction and maintenance to reduce erosion in the Normanby catchment, especially on sodic soils. Include identifying road erosion "hotspots"/ erodible soils, improving road draining to reduce gullying, and avoiding cycles of reconstruction after each wet season. | Catchment wide- Numerous HEV ecosystems are threatened by the cumulative impacts of roads. | **HIGH**<br>Cook Shire, Qld Main Roads, local operators and NRM groups |
| 4.2 | Workshops with Cook Shire, Qld Main Roads and local operators to trial and adopt the draft BMP guidelines and update/ improve guidelines over time. | As above; On-ground investments should focus on erosion prone soil areas | **HIGH**<br>NRM groups |
| 4.3 | Trial and implement alternative fencing methods to reduce erosion. Assist landholders to identify suitable fence & track locations and erosion reduction methods based on topography & soil types. | As above | **HIGH**<br>Reef Rescue, NRM groups, landowners |
| 4.4 | Upgrade roads to minimize erosion at high erosion sites and assess options for relocating sections of roads adjacent to HEV wetlands | Catchment Wide and localised.<br>Rinyirru (Lakefield) NP; 6 Mile Waterhole, Catfish Lagoon, Old Faithful, Horseshoe Lagoon, Kennedy Bend, Breeza, White | **HIGH**<br>QPWS, Cook Shire, Qld Main Roads |
| 4.5 | Move campsites away from the water's edge at National Park areas- rotate camping sites to allow for re-vegetation. | Rinyirru (Lakefield) NP | **MEDIUM**<br>QPWS |

## TABLE 11: FIRE MANAGEMENT ACTION GOAL AND PRIORITY ACTIONS

| MANAGEMENT ACTION GOAL 5<br>**FIRE** | **Reduce occurrence of late-dry season (high intensity) fires to protect river frontage zones, increase late-dry season vegetation cover, and reduce sediment/nutrient run-off into streams.**<br>**Less than 20% of catchment burnt in late-dry season each year and the same areas are not burnt each year.** |
|---|---|

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 5.1 | Conduct catchment wide coordinated Fire Planning to balance management needs, identify appropriate fire regimes for riparian areas and river frontage country, reduce the area of high-intensity late-dry season burns, and ensure the same areas are not burnt each year. Avoid consistently using riparian zones and river frontage as fire breaks. Monitor annual burns via NAFI and ground observations. | Catchment-wide impacts on downstream HEV areas | **HIGH**<br>Landowners, QFRS, QPWS, CYSF, NRM groups, Aboriginal Land Trusts |
| 5.2 | Provide assistance to landholders to adopt traditional mosaic burning regimes and conduct early-dry season burns to prevent late dry season fires, protect riparian vegetation and river frontage country and minimise impacts on water quality from erosion. | Catchment-wide; priority sites as per mapped erosion hot spots | **HIGH**<br>Landowners, QFRS, QPWS, CYSF, NRM groups, Land Trusts |
| 5.3 | Conduct research into the most suitable fire regime for riparian areas and erodible soils to reduce fire impacts on erosion and water quality. This research should involve property or multiple property scale fire management trials and monitoring of erosion and water quality impacts. | Catchment-wide HEV ecosystems; priority trial sites as per mapped erosion hot spots | **HIGH**<br>Research organisations, land owners, NRM groups |

*Farmers and land managers can also earn carbon credits through Early-Dry Season Savanna Burning (Australian Government 2013)

### TABLE 12: MINING AND EXPLORATION ACTION GOAL AND PRIORITY ACTIONS

| | |
|---|---|
| MANAGEMENT ACTION GOAL 6<br>**MINING & EXPLORATION** | **Mining & Exploration within the Catchment does not occur at HEV or HCV sites or alter water quantity or quality at these sites. Proposed mining activities are rigorously evaluated for impacts on water quality & quantity.**<br>**Cumulative impacts of multiple mines and related infrastructure are assessed in planning and approval, along with adequate monitoring of impacts.** |

| Action | Management Action | HEV/HCV area | Priority Level & Key Organisations |
|---|---|---|---|
| 6.1 | Approval of mining exploration permits to take into account the cumulative impacts on HEV and HCV aquatic ecosystems including those listed in Section 5.6 (i.e., surface water quality and quantity, groundwater, earthworks, roads, weeds, shipping impacts, metals and contaminants, oils, fish, seagrass, turtles, dugong, dolphin, etc.). | Catchment wide | **HIGH**<br>Federal & State Government |
| 6.2 | Conduct baseline studies on surface and groundwater resources necessary for assessment of mining impacts including: groundwater and surface water connectivity; baseline water quality outside of existing monitoring areas in the catchment; water flow for environmental needs at downstream HEV sites, and potential impacts on Environmental Values. Develop local Environmental Water Flow Guidelines. | Catchment wide- anywhere mining & exploration is proposed | **HIGH**<br>QDRNM |
| 6.3 | Approved exploration and production activities are monitored in detail for impacts on water quality and quantity (environmental flows). Where guidelines are exceeded, mines are required to STOP WORK until guidelines can be met. Independent monitoring and auditing by 3rd parties to ensure compliance. | Catchment wide | **HIGH**<br>Qld government,<br>Independent Research organisations,<br>Mining corporations. |
| 6.4 | Manage increased recreational access and activities in mine areas (fishing pressure, 4wd, spread of weeds, etc.) | Mine Developments | **MEDIUM**<br>Qld government, Mining corporations, Land Trusts |

### TABLE 13: WEEDS AND FERAL ANIMALS ACTION GOALS AND PRIORITY ACTIONS

| MANAGEMENT ACTION GOAL 7<br>**WEEDS & FERAL ANIMALS** | **Reduce impacts on water quality, riparian and aquatic vegetation from feral pigs, cattle and horses.**<br>**Reduce weed infestations at HEV and HCV aquatic areas & avoid further spread of weeds to riparian zones and river frontage areas .** |
|---|---|

| Action | Management Action | HEV/HCV Area | Priority Level & Key Organisations |
|---|---|---|---|
| 7.1 | Continue and increase feral animal control methods at unfenced HEV and HCV areas (aerial and ground shooting, baiting, trapping, especially biological control). | Priority HEV and HCV wetlands | **HIGH**<br>QPWS, CYWAFAP, landholders, NRM groups |
| 7.2 | On-going Treatment to eradicate Hymenachne from Rinyirru NP; identify and target upstream sources in the catchment (i.e. Kalinga Station). | Rinyirru NP | **HIGH**<br>QPWS, CYWAFAP |
| 7.3 | Reduce the spread of Sicklepod along river frontage country by providing assistance to landholders for management and researching biological control options. | Laura & Normanby Rivers | **HIGH**<br>CYWAFAP, QPWS, landholders, NRM groups |
| 7.4 | Survey HEV wetlands and cultural sites and identify priority sites for feral animal exclusion fencing and appropriate fence sites. Implement fencing and long-term monitoring and maintenance of fences. | Priority HEV wetlands as identified.(e.g., Jack Lakes “Top Lake”). | **MEDIUM**<br>QPWS, CYWAFAP, landowners and Aboriginal Land Trusts with govt. support |
| 7.5 | On-going monitoring for recurrence of Salvinia in the Laura River | Laura River, Rinyirru NP | **MEDIUM**<br>SCYC, Laura Rangers |
| 7.6 | Reduction of dominance of pasture weeds that compete with native perennial grasses, increasing water run-off and promote erosion. Assist landowners with weed management in native and improved pastures. | Upper catchment grazing properties | **MEDIUM**<br>CYWAFAP, DAFF, Reef Rescue, NRM groups |
| 7.7 | Reduction of Rubbervine along Normanby & Laura Rivers via rust and other treatments where appropriate; map Rubbervine areas and monitor outcomes of treatments | Laura & Normanby Rivers; Rinyirru NP | **MEDIUM**<br>CYWAFAP, QPWS, landholders, NRM groups. |

## TABLE 14: MONITORING AND RESEARCH GOALS AND PRIORITY ACTIONS

| MANAGEMENT ACTION GOAL 8<br>**MONITORING & RESEARCH PRIORITIES** | **Improve empirical knowledge of nutrient/sediment loads, sources & deposition zones in the Normanby and PCB.**<br>**Monitor land-use management regimes for impacts &/or improvements in water quality and quantity.**<br>**Identify BMPs specific to local land use and land-type.**<br>**Monitor HEV & HCV aquatic ecosystems for baseline condition & potential impacts from changes in water quality or quantity.** |
|---|---|

| Action | Monitoring and Research Action | HEV/HCV Area or Priority Research Sites | Priority Level & Key Organisations |
|---|---|---|---|
| **WATER QUANTITY AND QUALITY** | | | |
| 8.1 | Research on surface and groundwater resources, including aquifer recharge rates and connectivity between groundwater and surface water springs in the Laura Valley and upper Normanby catchment.<br>Develop Water Resource Plan for the upper catchment. | Laura River, East and West Normanby Rivers | **HIGH**<br>DNRM, Laura rangers, Research Organisations, |
| 8.2 | Monitor environmental water flows at springs, streams, and rivers; particularly downstream from current and proposed water extraction and impoundment sites. Assess potential impacts on downstream water availability, water quality and environmental values. Develop Environmental Water Flow Guidelines. | Laura River, East and West Normanby Rivers | **HIGH**<br>DNRM, Laura rangers, Research Organisations, |
| 8.3 | Develop a “Super Gauge” approach at key river gauge sites to better quantify long-term water, sediment and nutrient loads and actual changes over time. Use continuous surrogate measurements of suspended sediment and bedload along with width and depth integrated samples. | Normanby at Kalpowar, Battle Camp, East & West Normanby, Laura River, Hann. Re-instate the West Normanby gauge to quantify the erosion “hot spot”. | **HIGH**<br>DNRM & DSITIA, Research Organizations |
| 8.4 | Improve monitoring of nutrient and sediment loads delivered to PCB from Normanby, Bizant, Kennedy and Marrett River (flood events and tidal flushing). Improve load calculations(sediment and nutrients) and develop loads targets. | Normanby River, Rinyirru National Park, Princess Charlotte Bay and GBR | **HIGH**<br>DNRM & DSITIA, Research Organisations,<br>Lama Lama Rangers, SCYC |
| **LAND USE IMPACTS** | | | |
| 8.5 | Research into river sedimentation (sand/silt from gully and bank erosion and in-filling of rivers and wetlands<br>Identify key deposition areas- wetlands and river channels<br>Compare current and historic rates of deposition<br>Quantify the effects on surface water flow and habitat for aquatic animals (fish, turtles) | Catchment-wide HEV ecosystems: Downstream of mapped erosion hot spots; Jack Lakes (Top Lake); other sites as identified by Traditional Owners, QPWS, Brooks et al (2013), etc. | **HIGH**<br>Research Organizations, Traditional Owners, NRM groups |

| Action | Monitoring and Research Action | HEV/HCV Area or Priority Research Sites | Priority Level & Key Organisations |
|---|---|---|---|
| 8.6 | Research appropriate fire regimes for erosion management, weed control, and pasture productivity on hillslopes and river frontage country. | Catchment wide | **HIGH**<br>Research Organizations, Aboriginal Land Trusts, NRM groups, QFRS |
| 8.7 | Develop effective methods for weed control using innovative techniques (competition, biological, mechanical, chemical). | Catchment wide | **HIGH**<br>Research Organisations, CYWAFAP, Landowners |
| 8.8 | Better quantify the extent that European land use practices (grazing, agriculture, roads, fences, fires) have elevated sediment and nutrients levels in local and downstream water bodies and coastal areas. | Catchment wide | **MEDIUM**<br>Research Organisations, NRM groups |
| 8.9 | Develop a better understanding of land use drivers of bank erosion in small alluvial channels | Catchment-wide HEV ecosystems; Mapped erosion hot spots | **MEDIUM**<br>Research & NRM groups |
| | **GULLY EROSION** | | |
| 8.10 | Researching effects of cattle exclusion or spelling in river frontage on vegetation and alluvial gully erosion rates. Large-scale, long-term trials of improved land management practices (cattle, fire, weeds, roads, fences) are needed in mapped areas of alluvial gully erosion and high erosion potential soils along river frontage. Detailed monitoring of erosion and water quality outcomes is needed along with adaptive management. Reassess BMPs for erosion reduction and ABCD Framework. | Upper catchment areas; mapped erosion hot spots. | **HIGH**<br>Research Organizations, NRM groups, Landowners |
| 8.11 | Assess the market potential for payments for ecosystem services (soil, carbon, biodiversity retention) to reduce alluvial gully erosion along river frontage at the property and landscape scale. | Mapped erosion hot spots | **HIGH**<br>Research Organizations |
| 8.12 | Fully develop gully prevention and rehabilitation BMP guidelines applicable to the Normanby catchment and northern Australia, building off preliminary work by Shellberg and Brooks (2013) and further research outcomes from 8.11 above. | Mapped gully erosion hot spots | **MEDIUM**<br>Research Organizations, NRM groups, Landowners |
| 8.13 | Investigate the mechanisms of gully initiation and acceleration from cattle tracks (pads) (i.e., animal migration patterns, vegetation grazing patterns, water runoff acceleration along tracks and down pre-existing gully features, re-vegetation and recovery). | Mapped gully erosion hot spots | **MEDIUM**<br>Research Organizations, NRM groups, Landowners |
| 8.14 | Trial the effectiveness of intensive gully control measures such as head-cut drop structures and water diversion banks in high dispersive sodic soils. | Mapped gully erosion hot spots | **MEDIUM**<br>Research Organizations, NRM groups, Landowners |
| 8.15 | Assess the costs and economic viability of alluvial gully erosion control measures, along with an assessment of socio-economic impacts and environmental benefits. | Mapped gully erosion hot spots | **MEDIUM**<br>Research Organizations |

| Action | Monitoring and Research Action | HEV/HCV Area or Priority Research Sites | Priority Level & Key Organisations |
|---|---|---|---|
| 8.16 | Research the potential for aerial seeding appropriate grass species to reduce gully erosion across large areas, as well as the germination and growth success of a variety of grass species in dispersible sodic soils. | Mapped gully erosion hot spots | **MEDIUM**<br>Research Organizations, DAFF, NRM groups<br>Landowners |
| **MARINE AND COASTAL** | | | |
| 8.17 | Investigate and identify dominant sources of nutrients and sediments in PCB flood plumes (inc. sediment tracing and nutrient isotopes) | PCB marine ecosystems including GBR and seagrasses areas. | **HIGH**<br>Research Organizations,<br>Lama Lama Rangers, SCYC |
| 8.18 | Research coastal erosion processes in the lower Normanby coastal plain, to understand whether this process constitutes a long-term threat to the GBR. | PCB marine ecosystems including seagrasses and GBR | **HIGH**<br>NRM groups, Research organisations |
| 8.19 | Undertake research on the coral reefs surrounding PCB (cores and direct measurement) to determine the relationship between catchment land use and sediment/nutrient export to the reef. | PCB marine ecosystems including seagrasses and GBR | **HIGH**<br>Research organisations & NRM groups |
| 8.20 | Investigate the role of shipping induced sediment re-suspension in the shipping lanes off PCB and the potential impact of the resuspended sediment on nearby reefs. | PCB marine ecosystems including seagrasses and GBR | **HIGH**<br>Research Organizations, NRM groups |
| 8.21 | Monitor coastal & reef seagrass meadows in Princess Charlotte Bay & Bathurst Bay | PCB/ GBR | **MEDIUM**<br>GBRMPA MMP, JCU, Lama Lama rangers |
| 8.22 | Monitor coral reef health at PCB, Clack Reef, Corbett Reef and the Flinders Islands | PCB/ GBR | **MEDIUM**<br>GBRMPA, QPWS |
| 8.23 | Monitor turtle & dugong populations in PCB | PCB/ GBR | **MEDIUM**<br>QPWS, Lama Lama |
| 8.24 | Investigate sources of OC pesticides and hydrocarbons in mud crabs at PCB; analyse sediment samples from Normanby and other PCB estuaries | Normanby estuary and PCB | **LOW**<br>Qld Fisheries, Research Organisations |
| 8.25 | Investigate sources of herbicides at Hannah Island (deploy passive samplers at potential source catchments) | Princess Charlotte Bay & GBR | **LOW**<br>DSITIA, Lama Lama |
| **ENVIRONMENTAL VALUES ASSESSMENTS** | | | |
| 8.26 | Survey Environmental Values (i.e. biodiversity, cultural values and aquatic ecosystem condition) and systematically assess and categorize HEV and HCV aquatic ecosystems. | Rinyirru (Lakefield) NP; Pollys Lake and Pelican Lake/ Jack River NP: Barneys Lake/ HEV river systems (Granite Normanby, Laura Sandstone region) | **MEDIUM**<br>QPWS, Traditional Owners, NRM groups and research partners |

# 7 WATER QUALITY GUIDELINES AND TARGETS

## 7.1 Dry Season, Wet Season and Flood Event Water Quality Guidelines

There are no water quality guidelines specific to Cape York Peninsula, with the exception of the Endeavour River estuary (Qld Water Quality Guidelines 2009). The existing water quality datasets (CYMAG, AIMS and DERM/DSITIA) have been used to derive water quality guidelines for sections of the Normanby catchment. These guidelines have been determined for dry season baseflow, wet season baseflow and wet season flood event conditions based on the 20$^{th}$, 50$^{th}$ and 80$^{th}$ percentiles of the existing datasets, which were collected between 1968 - 2013 but concentrated between 2006 - 2013. The parameters vary depending on the availability of data and relevance for setting water quality targets. For small datasets, dry season and wet season baseflow values have been combined.

Sample results were categorized as dry season baseflow, wet season baseflow or wet season flood event based on the river height, antecedent rainfall, field observations, and turbidity or suspended sediment concentrations.

For some indicators, the number of samples collected is less than the minimum recommended for setting guidelines [ANZECC 2000 (n = 24), DEHP 2009 (n = 18)]. Flood event guidelines for some sites were derived based on samples collected primarily from the 2012 - 2013 flood events. For these situations, the percentiles represent interim guidelines and further sampling and/or comparison with DSITIA data (where available) is recommended.

There is insufficient data for rivers in the western region of the catchment (including the Hann, Morehead, Kennedy, and Annie Rivers and Saltwater Creek). Further assessments of threats, current condition and monitoring of water quality is warranted in these areas.

Where water quality is considered to be in reference (natural) condition, the targets for water quality are to protect and **maintain** the current condition. Where increases in nutrient or suspended sediment concentrations have occurred that may be affecting HCV or HEV aquatic ecosystems, the target is to **reduce** ambient or wet season (flood) concentrations from the current condition.

Guidelines and water quality objectives are based on concentrations. No targets have been set for nutrient or sediment loads entering Princess Charlotte Bay as there is inadequate data available to derive current end of system loads or to set loads targets. However, nutrient and sediment loads have been calculated at stream gauging sites.

## TABLE 15: UPPER LAURA RIVER (LAKELAND REGION TO CARROL'S CROSSING) WATER QUALITY GUIDELINES

| Percentile Range | pH | Conductivity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlorophyll-a | SSC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | mS/cm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Dry Season Baseflow** | | | | | | | | | | | |
| **20th** | 8.00 | 0.861 | 57.77 | 1.3 | 0.02 | 0.004 | 0.001 | 0.001 | 0.23 | 0.96 | **ID** |
| **50th** | 8.40 | 1.043 | 81.47 | 2.0 | 0.03 | 0.006 | 0.005 | 0.003 | 0.31 | 1.77 | **ID** |
| **80th** | 8.64 | 1.257 | 98.00 | 3.0 | 0.05 | 0.013 | 0.011 | 0.046 | 1.00 | 4.05 | **ID** |
| **n** | 39 | 39 | 39 | 39 | 36 | 36 | 36 | 36 | 34 | 33 | |
| **Wet Season Baseflow** | | | | | | | | | | | |
| **20th** | *7.91* | *0.653* | *72.98* | *4.00* | *0.03* | *0.005* | *0.002* | *0.003* | *0.25* | *1.99* | **ID** |
| **50th** | *8.29* | *0.780* | *84.75* | *6.59* | *0.04* | *0.012* | *0.005* | *0.013* | *0.42* | *3.19* | **ID** |
| **80th** | *8.63* | *0.897* | *93.14* | *8.13* | *0.07* | *0.025* | *0.007* | *0.768* | *0.95* | *4.57* | **ID** |
| **n** | 12 | 12 | 12 | 15 | 17 | 17 | 17 | 17 | 17 | 10 | |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | 51.0 | 0.05 | 0.014 | 0.004 | 0.035 | 0.45 | -- | 38.0 |
| **50th** | -- | -- | -- | 128.8 | 0.09 | 0.026 | 0.009 | 0.114 | 0.71 | -- | 109.0 |
| **80th** | -- | -- | -- | 262.8 | 0.13 | 0.044 | 0.014 | 0.266 | 1.16 | -- | 279.4 |
| **n** | | | | 26 | 33 | 33 | 33 | 31 | 31 | | 16 |

ID= Insufficient Data for guidelines Numbers in italics (*1.42*) are Interim Guidelines- additional data required n = number of data points
Data Source: CYMAG, Howley unpublished, DSITIA (turbidity & TSS only)- should be cross-referenced with DSITIA nutrients data from Coal Seam gauge
Reference Sites: No reference sites are available for the Upper Laura River

**Environmental Values:** Irrigation, Stock water, Domestic Use
**Aquatic Ecosystem Condition:** Slightly to Moderately Disturbed
**Target 1:** Maintain Current Water Quality
**Target 2:** Maintain or reduce nutrient and chlorophyll values (orange highlighted cells)

**TABLE 16: MID- LOWER LAURA RIVER (CARROL'S CROSSING TO NORMANBY CONFLUENCE) WATER QUALITY GUIDELINES**

| Percentile Range | pH | Conductivity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlorophyll-a | SSC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | mS/cm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Dry Season Baseflow** | | | | | | | | | | | |
| **20th** | 7.78 | 0.281 | 50.63 | 2.0 | 0.01 | 0.001 | 0.001 | 0.001 | 0.16 | 0.64 | *2.8* |
| **50th** | 8.22 | 0.938 | 68.70 | 4.0 | 0.01 | 0.003 | 0.002 | 0.003 | 0.24 | 1.47 | *5.1* |
| **80th** | 8.45 | 1.268 | 88.60 | 6.9 | 0.02 | 0.004 | 0.004 | 0.005 | 0.39 | 2.07 | *10.0* |
| **n** | 39 | 39 | 39 | 75 | 36 | 36 | 36 | 36 | 35 | 30 | 16 |
| **Wet Season Baseflow** | | | | | | | | | | | |
| **20th** | *7.22* | *0.138* | *64.27* | 6.7 | *0.01* | *0.003* | *0.001* | *0.003* | *0.20* | *1.65* | *4.4* |
| **50th** | *7.65* | *0.232* | *81.87* | 16.7 | *0.02* | *0.004* | *0.003* | *0.010* | *0.25* | *2.05* | *9.5* |
| **80th** | *7.97* | *0.463* | *88.41* | 37.3 | *0.02* | *0.005* | *0.008* | *0.140* | *0.84* | *3.50* | *38.0* |
| **n** | 13 | 13 | 13 | 26 | 13 | 14 | 14 | 14 | 13 | 6 | 11 |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | 53.3 | 0.06 | 0.002 | 0.004 | 0.025 | 0.46 | -- | 140.0 |
| **50th** | -- | -- | -- | 164.3 | 0.12 | 0.006 | 0.006 | 0.093 | 0.81 | -- | 338.8 |
| **80th** | -- | -- | -- | 418.2 | 0.20 | 0.012 | 0.009 | 0.133 | 1.30 | -- | 1121.3 |
| **n** | | | | 22 | 26 | 25 | 25 | 25 | 25 | | 24 |

ID= Insufficient Data for guidelines Numbers in italics (*1.42*) are Interim Guidelines- additional data required n = number of data points
Data Source: CYMAG and Howley unpublished only- should be cross-referenced with DSITIA data from Coal Seam gauge
Reference Sites: Data was derived from 4 reference sites from the Festival Grounds to the Laura River at Old Laura Crossing

**Environmental Values:** Cultural Values, Recreational and Subsistence Fishing, Stock water, Domestic Use
**Aquatic Ecosystem Condition:** Slightly to Moderately Disturbed
**Target 1 :** Maintain Current Water Quality
**Target 2 :** Reduce suspended sediment values during flood events (orange highlighted cells)

## TABLE 17: EAST NORMANBY WATER QUALITY GUIDELINES

| Percentile Range | pH | Conductivity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlorophyll-a | SSC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | mS/cm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Baseflow (wet and dry season)** | | | | | | | | | | | |
| **20th** | 6.91 | 0.08 | 65.69 | 4 | 0.02 | 0.003 | 0.003 | 0.001 | 0.12 | 0.387 | *9* |
| **50th** | 7.30 | 0.11 | 74.03 | 5 | 0.02 | 0.005 | 0.004 | 0.002 | 0.15 | 1.085 | *20* |
| **80th** | 7.62 | 0.16 | 83.19 | 8 | 0.03 | 0.006 | 0.005 | 0.006 | 0.24 | 2.699 | *32* |
| **n** | 21 | 21 | 21 | 66 | 21 | 21 | 21 | 21 | 21 | 18 | 11 |
| **Wet season (all conditions)** | | | | | | | | | | | |
| **20th** | **ID** | **ID** | **ID** | 11 | 0.02 | 0.004 | 0.003 | 0.006 | 0.17 | **ID** | 32 |
| **50th** | **ID** | **ID** | **ID** | 56 | 0.05 | 0.005 | 0.005 | 0.057 | 0.47 | **ID** | 120 |
| **80th** | **ID** | **ID** | **ID** | 156 | 0.07 | 0.007 | 0.006 | 0.238 | 0.71 | **ID** | 294 |
| **n** | | | | 33 | 21 | 19 | 19 | 18 | 21 | | 32 |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | 29 | *0.04* | *0.004* | *0.004* | *0.048* | *0.37* | -- | 111 |
| **50th** | -- | -- | -- | 85 | *0.06* | *0.005* | *0.006* | *0.199* | *0.64* | -- | 135 |
| **80th** | -- | -- | -- | 201 | *0.10* | *0.007* | *0.010* | *0.260* | *0.75* | -- | 415 |
| **n** | | | | *23* | *16* | *13* | *13* | *12* | *16* | | *25* |

ID= Insufficient Data for guidelines    Numbers in italics (*1.42*) are Interim Guidelines- additional data required    n = number of data points

Data sources: CYMAG, Howley unpublished data, DSITIA- turbidity and TSS

Reference Sites: East Normanby Bridge at Peninsula Development Rd & East Normanby Gauging Station

**Environmental Values:** Stock water

**Aquatic Ecosystem Condition:** Slightly to Moderately Disturbed

**Target 1 :** Maintain Current Water Quality

**Target 2 :** Reduce suspended sediment values during flood events (orange highlighted cells)

**TABLE 18: WEST NORMANBY WATER QUALITY GUIDELINES**

| Percentile Range | pH | Conductivity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlor-a | Suspended Sediment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | mS/cm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Baseflow (wet and dry season)** | | | | | | | | | | | |
| **20th** | **ID** | **ID** | **ID** | *2* | *0.02* | *0.004* | *0.003* | *0.004* | *0.13* | **ID** | 5 |
| **50th** | **ID** | **ID** | **ID** | *9* | *0.03* | *0.007* | *0.006* | *0.022* | *0.27* | **ID** | 11 |
| **80th** | **ID** | **ID** | **ID** | *33* | *3.64* | *3.613* | *3.605* | *3.620* | *3.78* | **ID** | 36 |
| **n** | | | | 16 | 6 | 6 | 6 | 6 | 6 | | 28 |
| **Wet season (all conditions)** | | | | | | | | | | | |
| **20th** | **ID** | **ID** | **ID** | *14* | *0.09* | *0.018* | *0.007* | *0.047* | *0.45* | **ID** | 20 |
| **50th** | **ID** | **ID** | **ID** | *97* | *0.14* | *0.025* | *0.009* | *0.154* | *0.88* | **ID** | 195 |
| **80th** | **ID** | **ID** | **ID** | *257* | *0.21* | *0.035* | *0.014* | *0.217* | *1.29* | **ID** | 554 |
| **n** | | | | 8 | 9 | 8 | 8 | 8 | 9 | | 23 |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | **ID** | *0.11* | *0.021* | *0.007* | *0.130* | *0.75* | -- | *198* |
| **50th** | -- | -- | -- | **ID** | *0.16* | *0.025* | *0.009* | *0.187* | *0.94* | -- | *357* |
| **80th** | -- | -- | -- | **ID** | *0.29* | *0.036* | *0.016* | *0.220* | *1.42* | -- | *649* |
| **n** | | | | | 6 | 6 | 6 | 6 | 6 | | 10 |

ID= Insufficient Data for guidelines Numbers in italics (*1.42*) are Interim Guidelines- additional data required n = number of data points
(Data sources: CYMAG, Howley unpublished data, DSITIA- turbidity and TSS)
Reference Sites: Old West Normanby Bridge at Mulligan Hwy and DNRM West Normanby Gauging Station (closed)

**Environmental Values:** Stock water, Cultural Values
**Aquatic Ecosystem Condition:** Slightly to Moderately Disturbed
**Target 1 : Maintain** Baseflow Water Quality
**Target 2 : Reduce** suspended sediment values during wet season and flood events (orange highlighted cells)

**TABLE 19: RINYIRRU /LAKEFIELD NATIONAL PARK FRESHWATER WATER QUALITY GUIDELINES**

| Percentile Range | pH | Conductivity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlorophyll-a | Suspended Sediment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | mS/cm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Dry Season Baseflow** | | | | | | | | | | | |
| **20th** | 7.12 | 0.137 | 61.78 | 3 | 0.01 | 0.002 | 0.001 | 0.001 | 0.14 | 1.156 | 2 |
| **50th** | 7.40 | 0.195 | 79.22 | 6 | 0.02 | 0.003 | 0.005 | 0.004 | 0.19 | 2.138 | 4 |
| **80th** | 7.71 | 0.245 | 87.61 | 10 | 0.02 | 0.005 | 0.012 | 0.013 | 0.26 | 4.153 | 7 |
| **n** | 40 | 40 | 40 | 40 | 57 | 57 | 57 | 57 | 57 | 31 | 21 |
| **Wet Season Baseflow** | | | | | | | | | | | |
| **20th** | **ID** | **ID** | **ID** | 34 | 0.02 | 0.004 | 0.010 | 0.017 | 0.33 | **ID** | 16 |
| **50th** | **ID** | **ID** | **ID** | 51 | 0.03 | 0.005 | 0.014 | 0.022 | 0.39 | **ID** | 31 |
| **80th** | **ID** | **ID** | **ID** | 123 | 0.05 | 0.007 | 0.019 | 0.030 | 0.50 | **ID** | 53 |
| **n** | | | | 26 | 62 | 60 | 60 | 60 | 60 | | 55 |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | 44 | 0.04 | 0.01 | 0.01 | 0.01 | 0.40 | -- | 23 |
| **50th** | -- | -- | -- | 90 | 0.06 | 0.01 | 0.01 | 0.02 | 0.50 | -- | 43 |
| **80th** | -- | -- | -- | 214 | 0.09 | 0.01 | 0.02 | 0.04 | 0.60 | -- | 78 |
| **n** | | | | 25 | 118 | 109 | 109 | 109 | 108 | | 114 |

ID= Insufficient Data for guidelines n = number of data points
Data Source: CYMAG, Howley unpublished DATA, AIMS, DSITIA
Reference Sites: Data was derived from 2 reference sites: Kalpowar Crossing and 12 Mile Waterhole

**Environmental Values:** Cultural Values, Domestic Use & Drinking Water, Recreational Fishing
**Aquatic Ecosystem Condition:** High Ecological Value
**Target 1 :** Maintain Current Water Quality

**TABLE 20: ESTUARY WATER QUALITY GUIDELINES**

| Percentile Range | pH | Salinity | Dissolved Oxygen | Turbidity | Total Phosphorus | Filt Reac Phosphorus | Ammonia Nitrogen | Nitrogen Oxides | Total Nitrogen | Chlorophyll-a | Suspended Sediment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | log[H+] | Ppm | %SAT | NTU | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | mg/L |
| **Baseflow (Dry and Wet Season)** | | | | | | | | | | | |
| **20th** | 7.79 | 9.7 | 64.63 | 8.7 | 0.02 | 0.001 | 0.001 | 0.011 | 0.21 | *0.82* | **ID** |
| **50th** | 7.97 | 30.0 | 73.75 | 28.6 | 0.03 | 0.004 | 0.013 | 0.042 | 0.27 | *1.82* | **ID** |
| **80th** | 8.10 | 37.4 | 84.27 | 44.8 | 0.04 | 0.008 | 0.028 | 0.087 | 0.35 | *2.32* | **ID** |
| **n** | 24 | 24 | 24 | 24 | 26 | 26 | 26 | 26 | 26 | 10 | 0 |
| **Flood Event** | | | | | | | | | | | |
| **20th** | -- | -- | -- | *36.0* | *0.02* | *0.006* | *0.014* | *0.019* | *0.38* | *0.10* | 15.60 |
| **50th** | -- | -- | -- | *60.8* | *0.05* | *0.009* | *0.024* | *0.033* | *0.46* | *1.09* | 54.42 |
| **80th** | -- | -- | -- | *71.0* | *0.08* | *0.014* | *0.044* | *0.041* | *0.61* | *2.21* | 77.71 |
| **N** | | | | 14 | 15 | 15 | 15 | 15 | 15 | 7 | 10 |

ID= Insufficient Data for guidelines n = number of data points Numbers in italics (*1.42*) are Interim Guidelines- additional data required
Data Source: CYMAG, Howley unpublished DATA
Reference Sites: 4 reference sites: Normanby River at mouth, Normanby River 5 km upstream from mouth, Bizant River at mouth and Kennedy River at mouth

**Environmental Values:** Cultural Values, Commercial and Recreational Fishing
**Aquatic Ecosystem Condition:** High Ecological Value
**Target 1:** Maintain Current Water Quality

## 7.2 Land and Aquatic Ecosystem Condition Targets

Targets for protecting or improving water quality can include maintaining land condition necessary for water quality outcomes and maintaining aquatic ecosystem condition as both an indicator and objective of good water quality.

In order to minimize suspended sediment entering the river system, the following land condition targets (Table 21) are presented for further discussion and research into the most appropriate targets. These do not represent all relevant land condition targets for achieving the water quality objectives; however these represent high priority actions and actions that are achievable with reasonable levels of investment. Recommendations for land management actions to achieve these targets are presented in Tables 8, 11 and 13.

**Table 21: Land Condition Targets**

| **Water Quality Objective: Reduce suspended sediment concentrations during flood events** | | | | |
|---|---|---|---|---|
| **Land Condition Indicator** | | **TARGET** | **Current condition** | **Likelihood of Achieving** |
| Ground cover on cattle grazing areas at the end of the dry season* | Percent Ground cover (including grass, mulch, dead leaves) | median value >80% | [1]Median 50 – 80% | Medium |
| | Percent Grass cover (grass only) | median value: 50% – 75% | [1]Median 20 – 50% | Medium |
| | Standing Biomass Dry matter (weight of dried grass) | >1000kg/hectare | <250 to 1600 | Medium |
| Cattle Access to River Frontage Country | Spelling or Permanent Exclusion from river frontage country at priority erosion hot spots | X ha spelled / excluded | | High (with high level of investment) |
| | Alternative water access (reduce cattle migration to river) | X No. of alternative water access sites | ? | High (with high level of investment) |
| Fire Management | % of catchment burnt hot each year (Sept- Dec) | <15% catchment wide, <5% river frontage with erodible soils | [2]Average 25% | High (with adequate support for land owners/ managers) |
| | Standing Biomass Dry matter (weight of dried grass) | 2000kg/ha required for appropriate fire regimes | <250 to 1600 | Low under current management practices |
| Riparian Weeds | Riparian zone percent weed cover | Reduction or No increase in weed cover in riparian zones | unknown | Low (sicklepod) to medium (rubbervine) |

1 Three properties (Shellberg & Brooks 2013)
2 NAFI 2002 – 2012 fire scar history

***Groundcover Measurements***

Minimum total ground cover (including grass, mulch, dead leaves) required to reduce erosion on grazing land is typically around 50% (McIvor et al. 1995; Evans 1998). Measuring standing perennial grass cover at the end of the dry season is considered to be a more appropriate measure, because it is the deep-rooted perennial grasses that provide erosion resistance and improved water infiltration. End of dry season perennial grass cover targets of 50%-80% are recommended for the Normanby (Shellberg and Brooks 2013).

**Table 21: Aquatic Ecosystem Condition Targets Table**

| Aquatic Ecosystem | TARGET | Current condition |
|---|---|---|
| PCB Seagrass Meadows | Maintain current extent and diversity of intertidal seagrass meadows | [1]Good |
| | Maintain current extent and diversity of seagrass meadows on Corbett and Clack reefs | [1]Good |
| Freshwater Wetlands at Jack Lakes and Rinyirru NP and other priority aquatic ecosystems | Reduce by X % the current extent of feral pig and cattle damage to priority wetlands | [2]Poor (improving at Rinyirru) |
| Coral Reefs at Princess Charlotte Bay (Clack, Corbett, etc.) | No decline in percent coral cover or species diversity | [3]Good |

1 Carter et al, 2012

2 Jim Mitchell, pers. comm., July 2013

3 Fabricius et al 2005. (No regular monitoring has been done.)

Recommendations for aquatic ecosystem monitoring are presented in Table 14.

## 8 Implementation of the PLAN

The formation of a Water Quality Partnership is recommended to direct the prioritization, design, implementation and monitoring of water quality improvement projects in the Normanby catchment. The Partnership ideally would include representatives from: Australian Government (Reef Rescue), QDSITIA, QDAFF, DDNRM, QPWS, SCYC, Cape York LandCare, Cape York NRM, CYSF, local grazing and farming reps, and local Traditional Owner groups, with additional advice provided by research organisations such as Griffith University and James Cook University with specific knowledge of the catchment.

The current lack of extension officers in Cape York contributes to the poor transfer of knowledge and alternative management practices between landowners, government and scientists, which could prevent many economic and environmental losses. An analysis of economic benefits of current practices compared to altered land management practices is also crucial for determining the best options for Cape York Peninsula graziers and implementing appropriate changes.

To implement many of the recommended changes in land management, funding will be required for implementing water quality improvement projects, the construction and maintenance of fences or other infrastructure, extension officers, monitoring of water quality, quantity, and associated outcomes, and compensation for the economic losses or benefits of graziers. This compensation could be in the form of payments for ecosystems services and stewardship, the purchase of priority areas and erosion "hotspots" for conservation purposes, and/or the promotion of 'improved pasture' development on stable and productive soils not prone to high erosion (e.g., basalt soils).

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**APPENDIX A-**
**DIRECTORY OF IMPORTANT WETLANDS IN AUSTRALIA: WETLAND CLASSIFICATION SYSTEM & CRITERIA FOR LISTING**

To be entered in the Directory of Important Wetlands in Australia, a wetland area must meet one or more of the following criteria (Env. Australia 2001):

1.It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

The wetlands classification system for the Directory of Important Wetlands is based on that used by the Ramsar Convention in describing Wetlands of International Importance, but was modified slightly to suit the Australian wetlands of national importance.

## A—Marine and Coastal Zone wetlands

1 Marine waters—permanent shallow waters less than six metres deep at low tide; includes sea bays, straits
2 Subtidal aquatic beds; includes kelp beds, seagrasses, tropical marine meadows
3 Coral reefs
4 Rocky marine shores; includes rocky offshore islands, sea cliffs
5 Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets
6 Estuarine waters; permanent waters of estuaries and estuarine systems of deltas
7 Intertidal mud, sand or salt flats
8 Intertidal marshes; includes saltmarshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
9 Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swampforests
10 Brackish to saline lagoons and marshes with one or more relatively narrowconnections with the sea
11 Freshwater lagoons and marshes in the coastal zone
12 Non-tidal freshwater forested wetlands

## B—Inland wetlands

1 Permanent rivers and streams; includes waterfalls
2 Seasonal and irregular rivers and streams
3 Inland deltas (permanent)
4 Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
5 Permanent freshwater lakes (> 8 ha); includes large oxbow lakes
6 Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes
7 Permanent saline/brackish lakes
8 Seasonal/intermittent saline lakes
9 Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
10 Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes
11 Permanent saline/brackish marshes
12 Seasonal saline marshes
13 Shrub swamps; shrub-dominated freshwater marsh, shrub carr, alder thicket on inorganic soils
14 Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils
15 Peatlands; forest, shrub or open bogs
16 Alpine and tundra wetlands; incl. alpine meadows, tundra pools, temporary waters from snow melt
17 Freshwater springs, oases and rock pools
18 Geothermal wetlands
19 Inland, subterranean karst wetlands

**APPENDIX B**
**EXTENT OF INTERTIDAL AND REEF TOP SEAGRASS MEADOWS AT MOUTH OF THE NORMANBY AND CLOSEST REEFS**
**(Source: Carter et al 2012)**

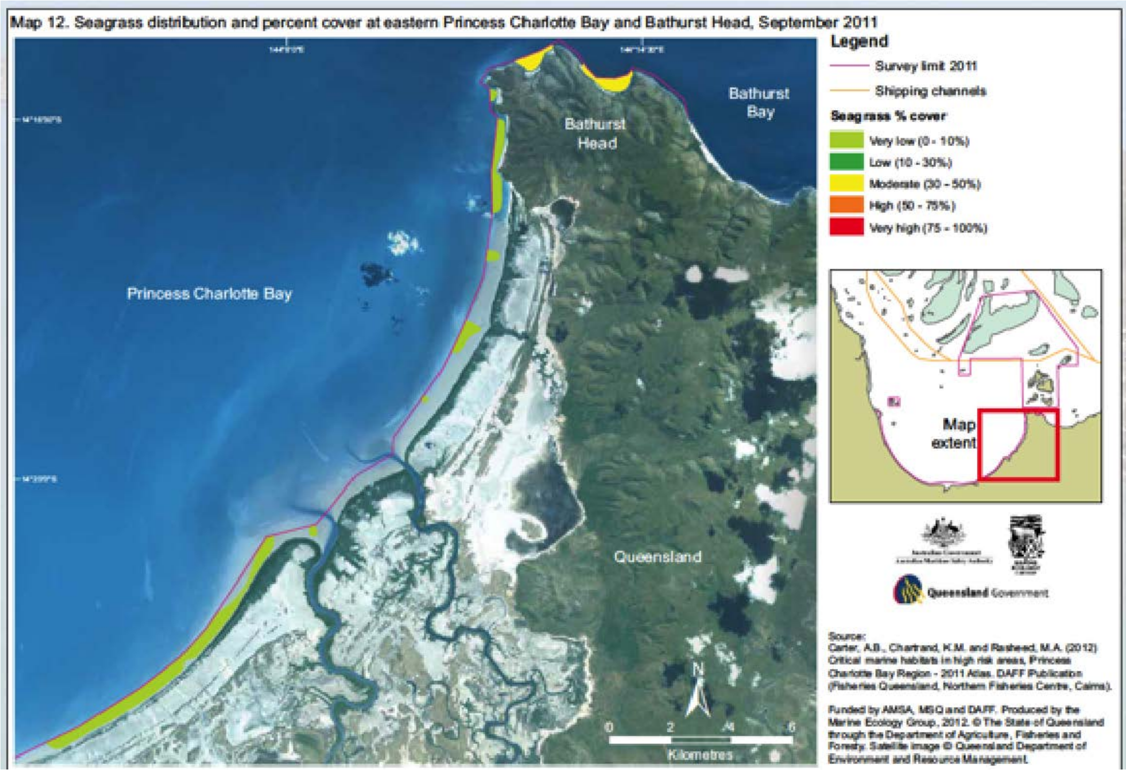


**Figure 19: Seagrass distribution and cover at mouth of the Normanby and Marrett Rivers**

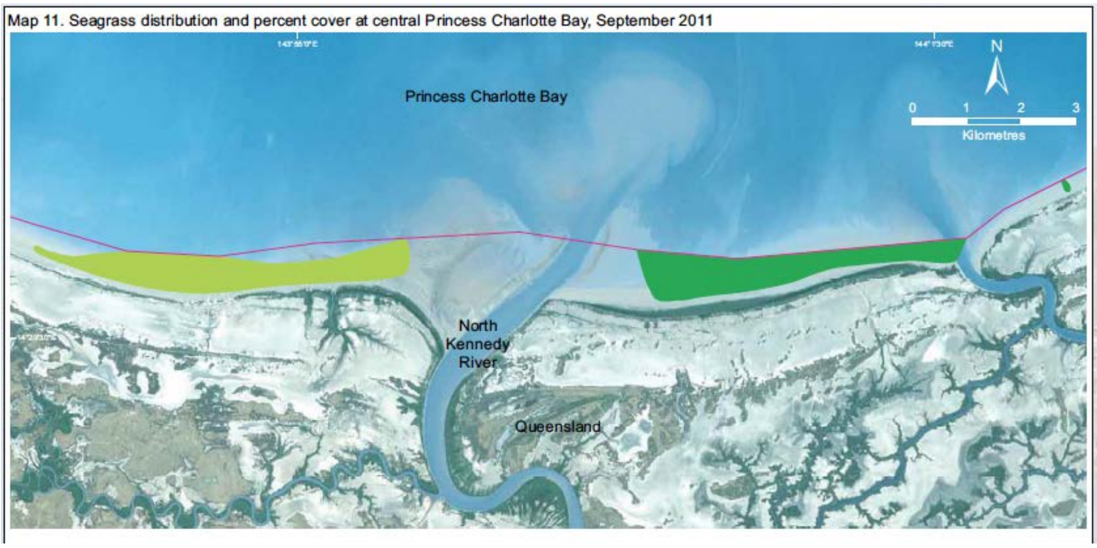


**Figure 20: Seagrass distribution and cover at mouth of the North Kennedy River**

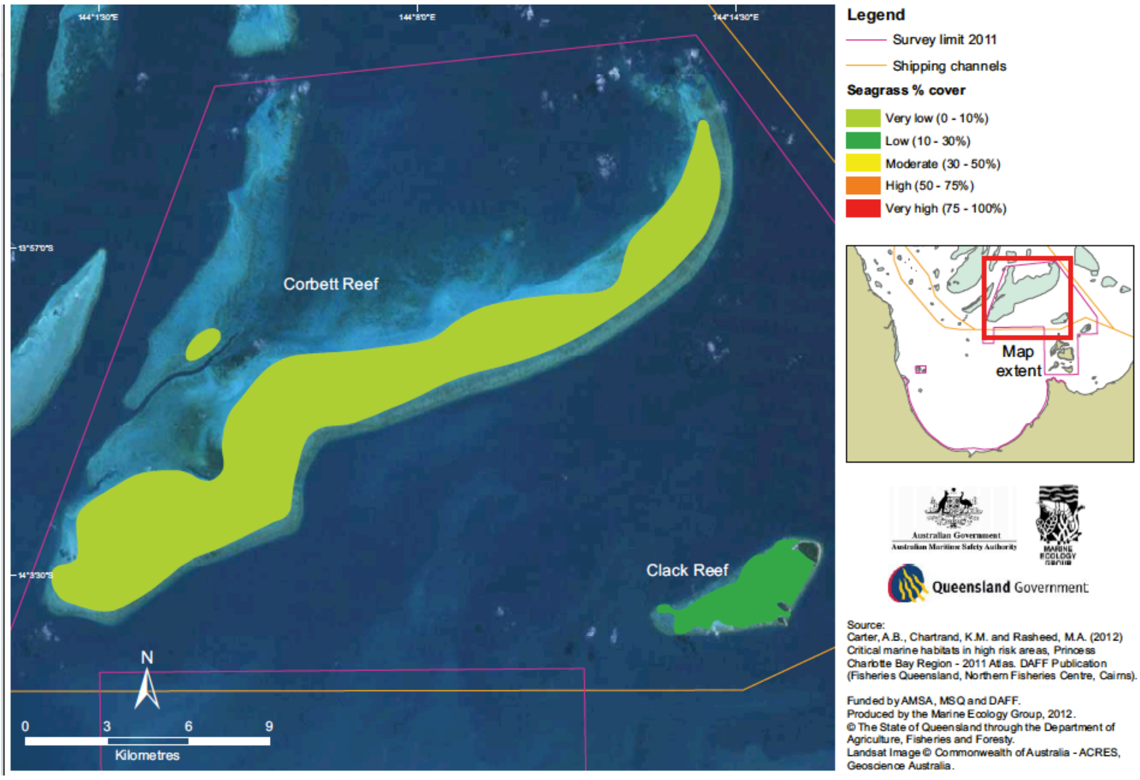


**Figure 21: Seagrass cover on Corbett and Clack Reefs, PCB**

**APPENDIX C**
**PROPOSED PRIORITY EROSION HOT SPOT / SOIL CONSERVATION AREA**

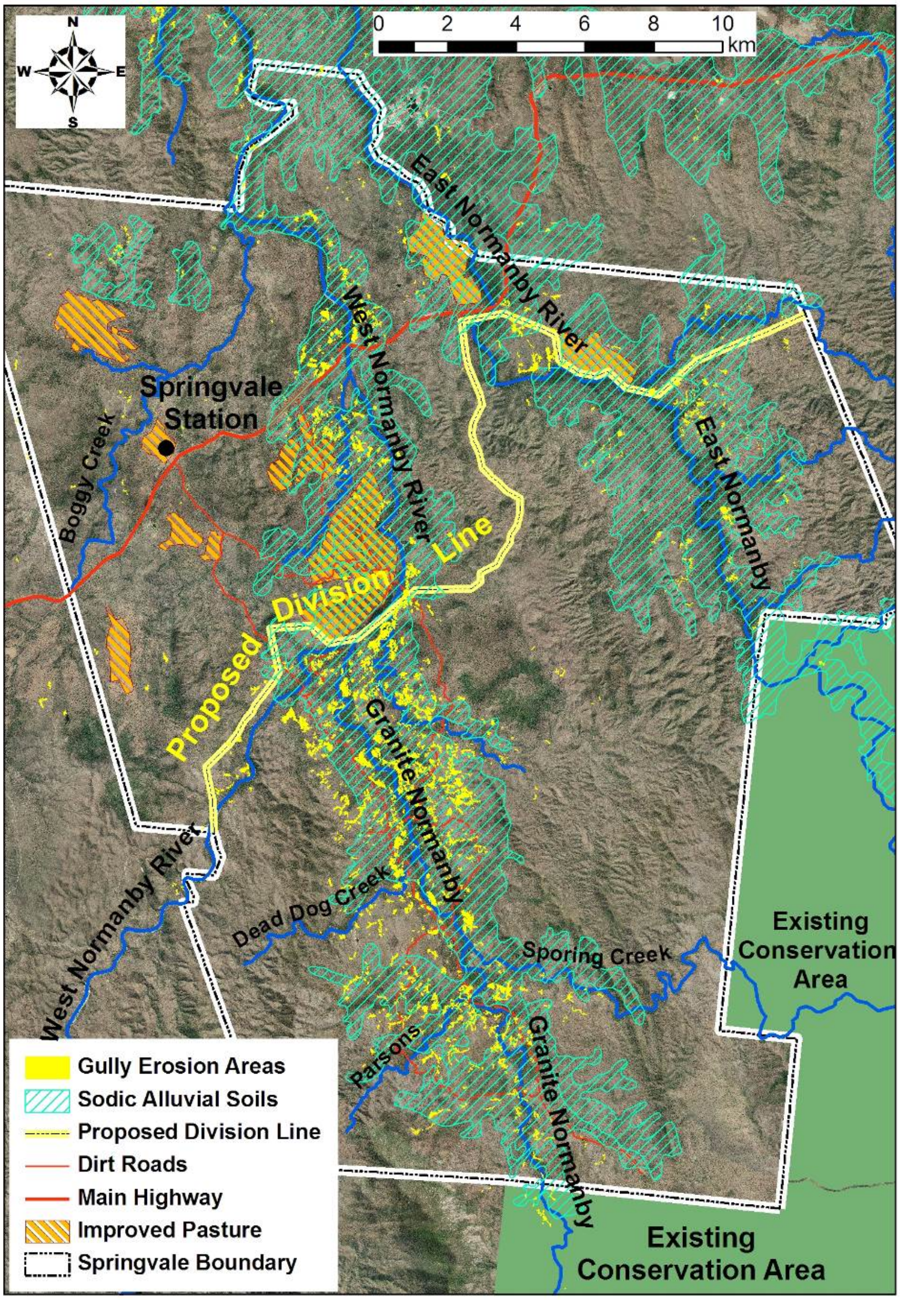


**Figure 22: Proposed Cattle Exclusion/ Conservation Zone on the Granite Normanby River**