FITZROY BASIN ASSOCIATION

Our country, Our future

Palm Tree & Robinson Creek Wetlands

Technical Reports and Management Guidelines – July 2014

Prepared by Cassandra Bouna, Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

This project is supported by Fitzroy Basin Association through funding from the Australian Government and Santos GLNG Project.

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Foreword

This land in the Dawson Valley on which we live, love and play is the common ground for all our lives. The water that sustains life - its rains, its streams, its swamps and lakes - are essential to every human life. The air we breathe is shared with all in our community. The health of these three elements is basic to food production, to healthy human reproduction and to the well-being of generations who may follow us in these early days in the European settlement of the Dawson Valley.

Over time, areas of forest have diminished to develop farming, timber, and pastoral enterprises, and the rush of early settlers has weakened to a small fraction of those who came in the 19th and early 20th centuries, expecting their children to enjoy an enhanced lifestyle in productive lands. Today another land-use change is upon us, and there are questions about whether the lessons from removing the former inhabitants – flora, fauna and human - have been learned before another wave of arrivals come to benefit from the resources of the land.

At this time, the Upper Dawson Branch of the Wildlife Preservation Society of Queensland determined that the importance of the Palm Tree and Robinson Creek wetlands be recognised.

Our Branch resolved that the natural values of the wetlands should be documented and recommendations be made for community and government management to ensure that the resources provided by them are preserved and enhanced for the future benefit of our communities. To achieve this objective, the Society partnered with the Fitzroy Basin Association (FBA) who sourced funding from the Australian Government and Santos GLNG to undertake a significant survey of the wetlands. The project included detailed studies of local history, flora and fauna, hydrology and water quality in the wetlands to determine their conservation significance and role as a landscape and wildlife corridor.

The hope now is that this project will allow those who seek to use this land to develop a better understanding of the dynamic and complex life-systems that occur in the wetlands to ensure their long term future.

We commend the work of the surveyors and compilers who have brought this publication to fruition and thank all who have played a part in its preparation.

Adam Clark (Project Officer) and Ann Hobson (Secretary)

Wildlife Preservation Society of Queensland – Upper Dawson Branch

June 2014

Acknowledgements

The Upper Dawson Branch of the Wildlife Preservation Society of Queensland (WPSQ) identified the need for detailed studies into the Palm Tree and Robinson Creek Wetlands and pursued a partnership with Fitzroy Basin Association (FBA) to make this a reality. FBA especially acknowledges the efforts of WPSQ Upper Dawson Branch members Adam Clark and Ann Hobson.

Funding for this project was provided by the Australian Government and Santos GLNG Project and is gratefully acknowledged. On-ground support was provided by Andrea Beard of Dawson Catchment Coordinating Association, one of FBA's delivery partners.

The following consultants identified the wetlands' values and provided an assessment of threats and management options for the site: Ray Lloyd of FaunaTrack (terrestrial vertebrate fauna), Allan Briggs of Birdlife Capricornia (avian fauna), Jason Halford & Rod Fensham of the University of Queensland (flora), Warren Lee Long, James Allen, Leonie Duncan and Ginni Glyde of Alluvium Consulting Australia (aquatic ecology, hydrology and social history studies), and Roger Jaensch of Jaensch Ornithology & Conservation (wetlands management guidelines).

The majority of the wetlands complex is located on private land. Therefore, the cooperation and contributions of landholders was integral to the success of this project. We thank the many property owners and managers for providing valuable information on the wetlands and/or for granting consultants access to their property to undertake field surveys.

Contents

Introduction

The Palm Tree and Robinson Creek Wetlands is an aggregation of at least 155 individual wetlands located 28 kilometres north of Taroom in the Dawson River catchment of the Fitzroy Basin, central Queensland. Listed on the Directory of Important Wetlands in Australia (DIWA), the site occupies 50,233 hectares and is roughly U-shaped, extending approximately 44 kilometres in a north-west to south-east orientation. The area is characterised by a series of shallow lakes and seasonal streams associated with Palm Tree and Robinson Creeks.

Queensland Government wetlands mapping from 2009 indicated there were 1.9 km^2 of lake wetlands and 24.1 km^2 of swamp wetlands within the DIWA site boundary. Robinson Creek has a catchment area of 1,840 km^2 while Palm Tree Creek has a catchment area of approximately 3,230 km^2. The greater floodplain swamps and lakes fill as a result of local runoff, small streams and riverine flooding from Palm Tree and Robinson Creeks. Wetlands in the Robinson Creek catchment are fewer, mostly larger and often wet for longer periods than those in the Palm Tree Creek catchment. Higher alluvial clay contents in the Robinson Creek wetlands and streams may contribute to the longer water retention periods here compared to the smaller, more temporary wetlands of the Palm Tree Creek catchment.

Current land use in the Taroom district is predominantly cattle grazing, with some cropping and resource industry exploration. Livestock utilise the wetlands for water and fodder, particularly during drier times when the wetlands hold greener and more abundant vegetation than the surrounding grassland. Landholders use the wetlands on their properties for recreation, while public recreation is centred on Lake Murphy Conservation Park, the only protected area within the wetland site.

Despite being a recognised site of national importance, detailed studies into the Palm Tree and Robinson Creek Wetlands had not been undertaken until 2013, advocated by the Upper Dawson Branch of the Wildlife Preservation Society of Queensland and coordinated by the Fitzroy Basin Association through funding from the Australian Government and Santos GLNG Project. Six areas of study were established – terrestrial vertebrate fauna, flora, birdlife, aquatic ecology, hydrology and social history. Consultants were contracted and delivered the reports in early 2014. A set of management guidelines were also developed, based on the findings in the reports, to guide land managers on how to protect the wetlands and ensure that they remain a productive and functional element of the landscape into the future.

During the course of the surveys, 235 native vertebrate species were recorded – including 143 bird species, 39 reptile species, 33 mammal species (including 14 bat species), 14 amphibian species and six fish species. Twenty-five of these species are of conservation significance, listed under commonwealth or state legislation. A total of 190 plant species were recorded in a detailed study of 52 wetlands, and while no threatened species were recorded, a number of uncommon species were detected.

The wetlands were deemed to be of particularly high ecological value to aquatic fauna providing both shallow and deep pools, large wood snags such as fallen trees, plus a diverse range of submerged, emergent and floating aquatic plants. Fish abundance was variable between wetlands, with the greatest abundance found in areas with aquatic plants. No fish were found in the upper catchment area of Palm Tree Creek, probably due to the ephemeral nature of this part of the catchment. This supported conclusions made by the hydrological study which detailed that the upper catchment wetland areas were less connected to the main stream. Freshwater shrimp were the most widespread and abundant macrocrustaceans, while snake-necked turtles were caught in two of the wetlands, and Krefft's River Turtle was previously caught in Lake Murphy. This indicates that at least two turtle species known from the upper Dawson Sub-Catchment inhabit the wetlands.

The hydrological study showed that groundwater appears to have relatively little influence on hydrology of the wetlands, although two Great Artesian Basin (GAB) springs confirmed downstream from the study area highlight there may be the potential for groundwater dependent springs in the wetlands. Sedimentation is an increasing area of concern, with significant shallowing and lateral expansion of wetlands. These changes may lead to more widespread flooding and alterations to watercourses during large rainfall events and are a concern for many landholders. Other major threats identified during the course of the studies included weeds (predominantly lippia and cat's claw creeper) and feral pigs, while potential future threats include loss of water supply through possible future dams or water harvesting. The Guidelines for Management report assesses these threats, and others, and provides responses aimed at mitigating the threats to the production and biodiversity values of the wetlands.

Terrestrial Vertebrate Fauna Report

FITZROY BASIN ASSOCIATION

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Terrestrial Vertebrate Fauna Report – Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by FaunaTrack for Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

The development of this report was supported by the Fitzroy Basin Association Incorporated (FBA) through funding from the Australian Government and Santos GLNG.

This report was prepared on behalf of FBA by FaunaTrack.

FAUNATRACK

Summary

This report presents the results of a terrestrial vertebrate fauna survey of the Palm Tree Creek and Robinson Creek wetlands near Taroom, Queensland during March and October 2013. The area is classified as an important wildlife refuge listed in the Directory of Important Wetlands in Australia (DIWA) and was the subject of a baseline vertebrate fauna survey as part of a biodiversity value assessment of the area.

The objectives of the survey were to:

- Compile an inventory of terrestrial vertebrate fauna (excluding birds, but including bats) associated with major vegetation types and representative wetlands of the area;
- Determine the species of conservation significance; and
- Obtain baseline data for management actions, in particular assessing important fauna habitats and assemblages present and detect any threats potentially impacting on species.

Surveys were conducted during March and October 2013, incorporating both the 'wet' and 'dry' seasons. A total of 12 systematic trapping sites were established for mammals, reptiles and amphibians. Additionally, insectivorous bat acoustic detectors were deployed at 21 locations, motion-sensitive cameras were deployed at 23 locations, frog censuses were carried out at 20 locations and call playback for nocturnal species was undertaken at 13 locations. Additional data was also obtained through a range of opportunistic and targeted surveys during the course of the survey, including some surveys of the bird fauna.

Key results were:

- Almost 230 native vertebrate species were recorded during the survey, including:
  - 143 species of bird;
  - 33 species of mammal (including 14 bat species);
  - 39 species of reptile; and
  - 14 species of amphibian.

- The Palm Tree and Robinson Creek wetland area contains a number of species of conservation significance, listed either under commonwealth or state legislation or as of regional significance within the Brigalow Belt South bioregion, these include:
  - 11 bird species;
  - 9 mammal species;
  - 4 reptile species; and
  - 1 amphibian species.

- Incorporating all available data on species within the DIWA boundary, the area comprises a total of 37 native mammal species, 42 species of reptile and 15 species of amphibian.

Several threats were also identified, which include:

- Feral animals, including:
    - Wetland destruction from the feral pig;
    - Predation by the feral and cat and European fox;
    - Potential habitat destruction and competition by the European rabbit and European hare; and
    - Potential negative impacts from the Cane toad.
- Invasive weeds;
- Grazing of livestock;
- Inappropriate fire regimes;
- Habitat loss and fragmentation; and
- Drought

The Palm Tree and Robinson Creek wetland area has appeared to have undergone major anthropogenic modification, with habitat loss through pastoral activities being the main source. Although large areas have been cleared and altered, several areas of potential high conservation value still remain including remnant Brigalow (*Acacia harpophylla*) woodlands, open Eucalypt forests and riparian vegetation containing large, hollow-bearing trees. In addition, the many wetlands present within the area, although subject to trampling and compaction by livestock and destruction from feral pigs, still provide habitat and refuge for many species of wildlife, in particular waterbirds and amphibians.

Acknowledgements

Sincere thanks are due to Graeme Armstrong, Lyn Marshall, Jenna Bishop (FBA) and Rod Hobson (NPRSR) for discussions, assistance and helpful advice throughout the project. Thanks also to Rod for sourcing help with some glider identifications and passing on a wealth of knowledge from the region. Thanks also to Nathan Willis and the rest of the staff at the Taroom NPRSR office for their assistance. Helpful and interesting discussions were held with Adam Clark, Ann Hobson, Melanie Simmons and Andrew Dinwoodie, all from the Wildlife Preservation Society of Queensland (Upper Dawson Branch), thanks to you all for your insight and knowledge of the area, and great stories. Thanks also Greg Ford (Balance! Environmental, Toowoomba) for doing a fantastic job on analysing bat data and for providing some useful references, and also to David Noonan at Global Air Express for assistance with freight, and the staff at Fleet Crew in Enoggera for vehicle hire.

Thanks also to Jacqui Brock (DEHP) and Lex Turner (DAFF) for all things permit and ethics related. Field work was conducted under the Scientific Purposes Permit WISP12586513 from the Department of Environment and Heritage Protection, and Animal Ethics approval CA 2012/11/648 from the Department of Agriculture, Fisheries and Forestry (DAFF).

Glossary and Acronyms

Alluvial	In reference to soil deposited by flowing water
Anthropogenic	Created by people or caused through human activity
Arboreal	Living or moving about in trees
Cryptic	Secretive or mysterious by nature
DEHP	Department of Environment and Heritage Protection
Diurnal	Active primarily by day
DIWA	Directory of Important Wetlands Australia
Echolocation	An animal's ability to detect objects through emitting and receiving back (via reflection) high-pitched sounds
Elliott Trap	A small, aluminium box trap used mainly for the trapping of small mammals
EPBC	Environmental Protection and Biodiversity Conservation
Ephemeral	Non-permanent or short-lived
Fossorial	Relating to digging or burrowing
Herpetofauna	A collective name for reptiles and amphibians
Nomenclature	A set system of names or terms, used particularly in science
Nocturnal	Active primarily by night
NPRSR	Department of National Parks, Recreation, Sport and Racing
Riparian	Pertaining to or situated on the banks of a river
Taxa	Plural of taxon, for the taxonomic category of species
Terrestrial	Living, growing or moving on land

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Figure 29 An example of a thick leaf-litter mat at the base of a Brigalow tree within an intact area of Brigalow woodland. Areas such as these are important habitats more many species of reptile, including the Brigalow Scaly-foot, but are extremely susceptible to fire. Large wood and debris piles are also important habitat requirements for many species, particularly the Yakka Skink, which construct burrow systems underneath these

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1 Introduction

1.1 Overview

FaunaTrack was commissioned by the Fitzroy Basin Association Inc. on behalf of the Wildlife Preservation Society of Queensland (Upper Dawson Branch) to survey and assess the significant vertebrate fauna of the Palm Tree Creek and Robinson Creek wetlands near Taroom, Queensland. The area is classified as an important wildlife refuge listed in the Directory of Important Wetlands in Australia (DIWA) and was the subject of a baseline vertebrate fauna survey as part of a biodiversity value assessment of the area.

1.2 Survey objectives

The objectives of the survey were as follows:

- Compile an inventory of terrestrial vertebrate fauna (excluding birds, but including bats) associated with major vegetation types and representative wetlands of the area;
- Determine the species of conservation significance; and
- Obtain baseline data for management actions, in particular assessing important fauna habitats and assemblages present and detect any threats potentially impacting on species.

2 Methods

2.1 Database searches

The following sources were consulted in the formulation of potential fauna lists:

- DEHP Wildlife Online;
- Queensland Museum (reptiles, frogs and mammals); and
- EPBC Act Protected Matters Search Tool;

These searches helped to identify a number of threatened species that may potentially occur within the study area (APPENDIX A). Species were then assigned to a likelihood presence category based on habitats present and distributional range. Categories were defined as follows:

- **Unlikely:** Area contains no suitable habitat or local records.
- **Possible:** Either suitable habitat or local records present.
- **Likely:** Both suitable habitat and local records present.
- **Known:** Records previously confirmed within area.

2.2 Survey timing

Surveys were conducted over two seasons (autumn and spring) during 2013. The initial 'pilot' survey was conducted from 25th – 31st March 2013. This enabled selection of potential trapping sites for subsequent surveys and also to undertake targeted frog surveys while conditions were suitable. Although no systematic trapping was undertaken during this time, bat detectors and motion cameras were deployed and targeted, nocturnal and opportunistic searches were carried out. Subsequent trapping was then conducted from 18th – 28th October, whereby the full spectrum of trapping and survey techniques were employed.

2.3 Site selection

Initial field inspection of the area in March 2013 resulted in the categorisation of the following broad fauna habitat types:

- Riparian woodland (including *Livistona* woodlands);
- Eucalypt woodland with shrubs (including *Acacia harpophylla*);
- Eucalypt woodland with grassy understorey;
- Rocky outcrops and hills; and
- Water bodies;

Twelve trapping sites were established within the area (Figure 1; APPENDIX B). Sites were selected based on a combination of factors, including:

- Representation of vegetation associations (Queensland Herbarium, 2013);
- Extent of 'intact' vegetation present;
- Areas of conservation value or ecological sensitivity (including the likelihood of containing species of conservation significance);
- Presence/absence of cattle;
- Accessibility (to leasehold properties); and
- Proximity to existing tracks to enable sites to be checked as early as possible each day.

Trapping sites were supplemented by a number of targeted search sites, which increased coverage, potential for species occurrence, and also allowed collection from habitats not included in within formal trapping sites.

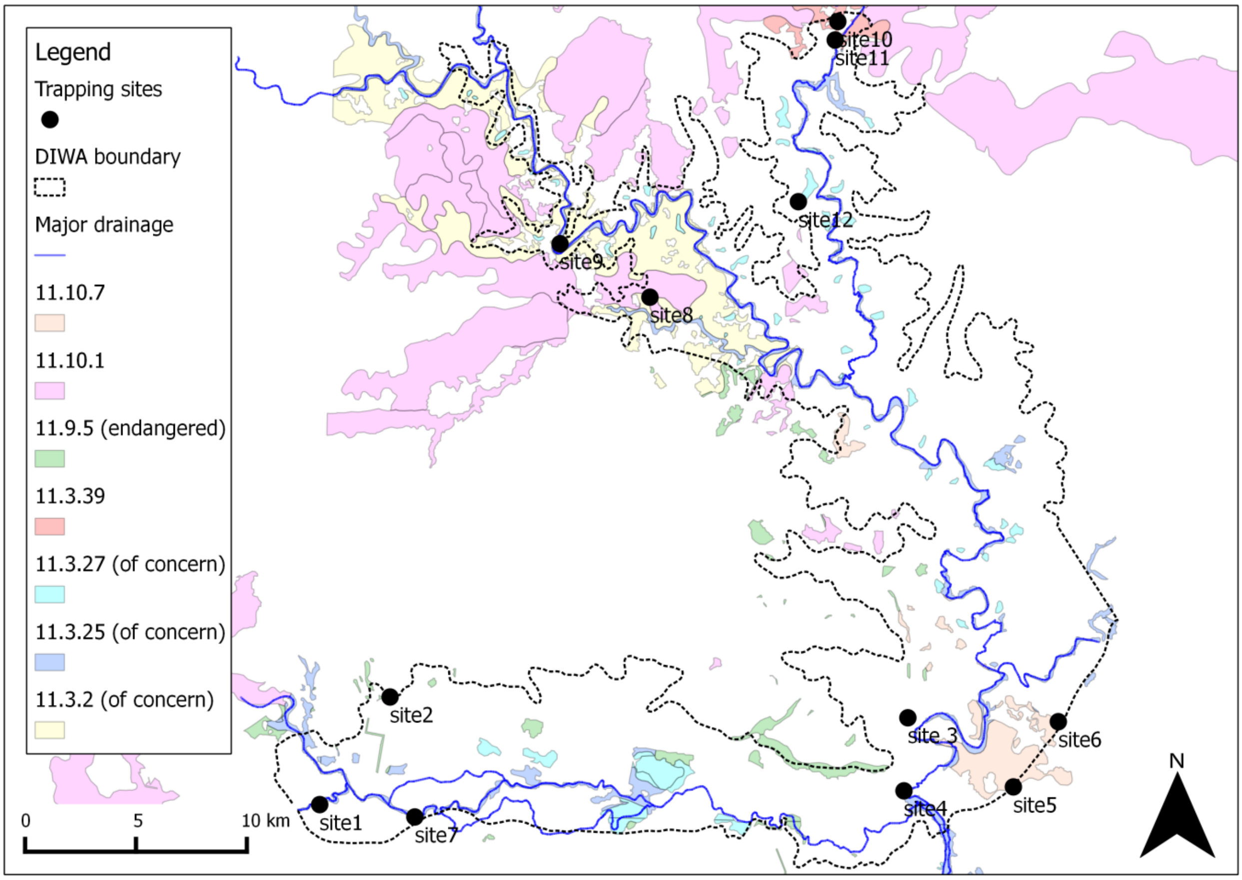

Figure 1 **Location of trapping sites and distribution of Regional Ecosystem types[1] and major drainage lines in which trapping sites were located.**

[1] **Sourced from www.ehp.gov.au/ecosystems/biodiversity/regional-ecosystems/**

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2.4 Sampling methods for vertebrate fauna

2.4.1 Trapping

Trapping for terrestrial mammals, reptiles and frogs was undertaken using conventional trapping techniques comprising a combination of pit-fall bucket traps, Elliott traps and funnel traps, with traps being open over four consecutive nights.

- *Pit-trap and drift fence*: Pitfall traps were used to target small terrestrial vertebrates. Four to five, 20 L plastic buckets (30 cm diameter, 40 cm deep) were established at each site. A 6-7 m length of flywire fencing (30 cm high) bisected the pits, aimed at directing fauna into the traps. Traps were placed approximately 15 m apart and arranged in either a linear line (i.e. riparian strips or wetland edges) or in a square in less linear habitats.
- *Elliott box traps*: Elliott traps (Elliott Scientific, Upwey, Victoria) were used to target small terrestrial mammals. A total of ten Elliott type ‘A’ aluminium box traps (9 x 9 x 32 cm) were arranged in a lineal line spaced approximately 10 m apart and baited with universal bait (peanut butter, rolled oats and sardines). Elliott traps were checked each morning within three hours of sunrise.
- *Funnel traps*: Funnel traps were used to target terrestrial vertebrates, particularly those less likely to be caught in pitfall buckets (i.e. larger snakes and Pygopodid lizards). Sixteen to twenty funnel traps were used at each site and placed in association with drift fences, whereby traps were placed at either end of drift fences.

2.4.2 Bat detection

Bat echolocation calls were recorded using two ANABAT SD1 bat detectors (Titley Scientific, Brisbane) and two Song Meter SM2BAT detectors (Wildlife Acoustics, Concord MA, USA). Calls were recorded at 21 sites, including each of the trapping site and opportunistically throughout the project area (Figure 2). At each site units were left unattended overnight, ensuring peak activity periods were sampled. Mr Greg Ford (Balance! Environmental, Toowoomba) subsequently identified acoustic calls.

2.4.3 Motion-sensor cameras

Up to 20 motion-sensor camera units (Bushnell, USA) were placed throughout the study area (Figure 3). Cameras were deployed during both survey events and were positioned at both systematic trapping sites and opportunistically throughout the area. Cameras were deployed in suitable habitat, positioned approximately 1 m from the ground, attached to a tree (or similar) and angled towards the ground. These were then baited with sardines and left uninterrupted for up to six consecutive nights.

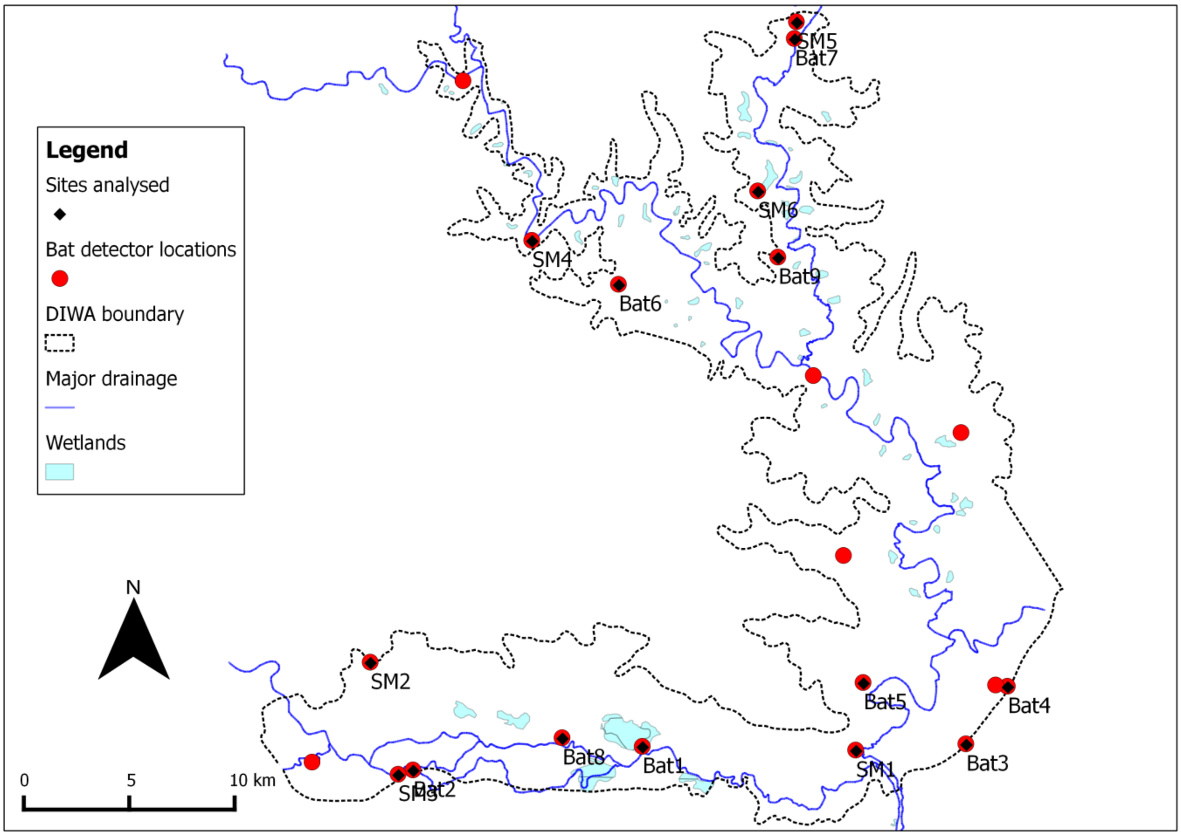


Figure 2 Location of bat detector units (red circle) and units with calls analysed (black diamond)

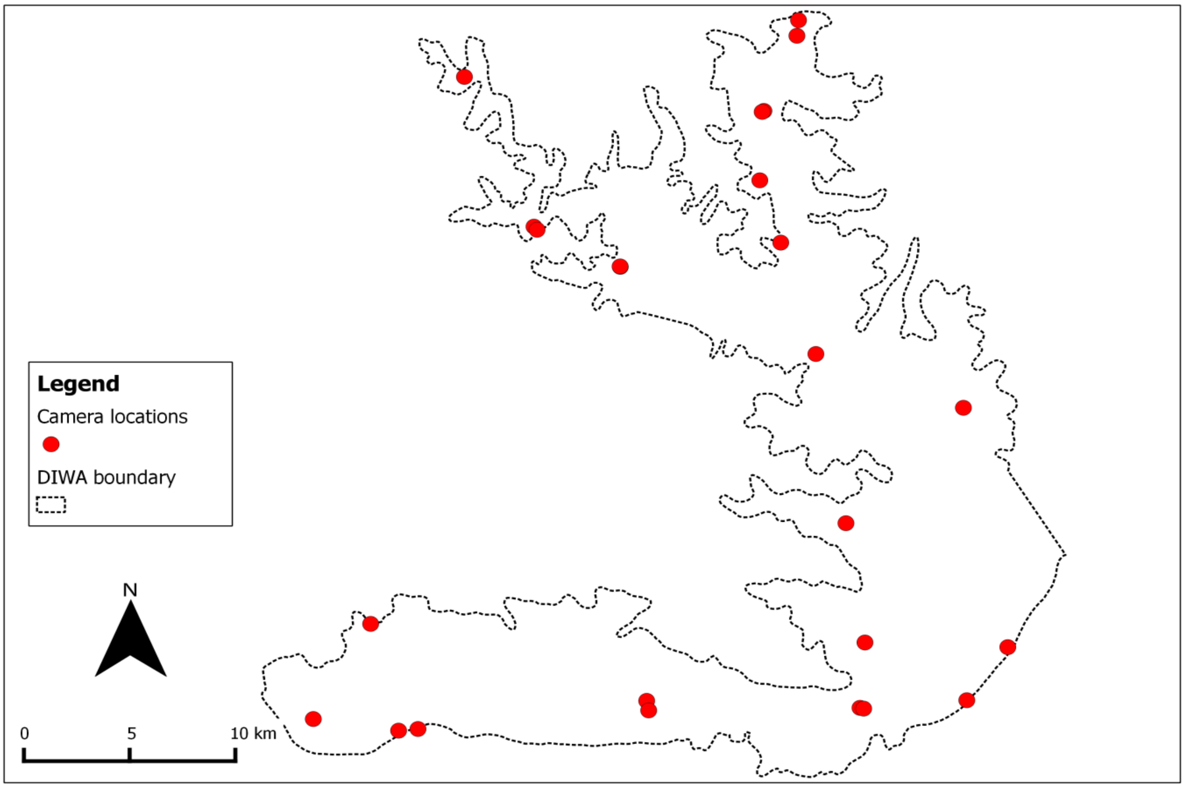


Figure 3 Locations of motion-sensor cameras

2.4.4 Frogs census

Searches for frogs were undertaken at a selection of accessible wetland and riparian habitats found within the DIWA (Figure 4). At each site, surveys were conducted predominantly at night with a head torch. Water bodies and their surrounds were carefully checked for distinctive 'eye shine' or the presence of active frogs. Five to ten minutes was also devoted to listening for calling males. Only presence/absence data was recorded, as opposed to specific numbers of species observed at each site. These sites also served as sites for general nocturnal searches, particularly for those species that are closely associated with wetland and floodplain habitats such as the Ornamental Snake (*Denisonia maculata*) and Grey Snake (*Hemiaspis daemelii*).

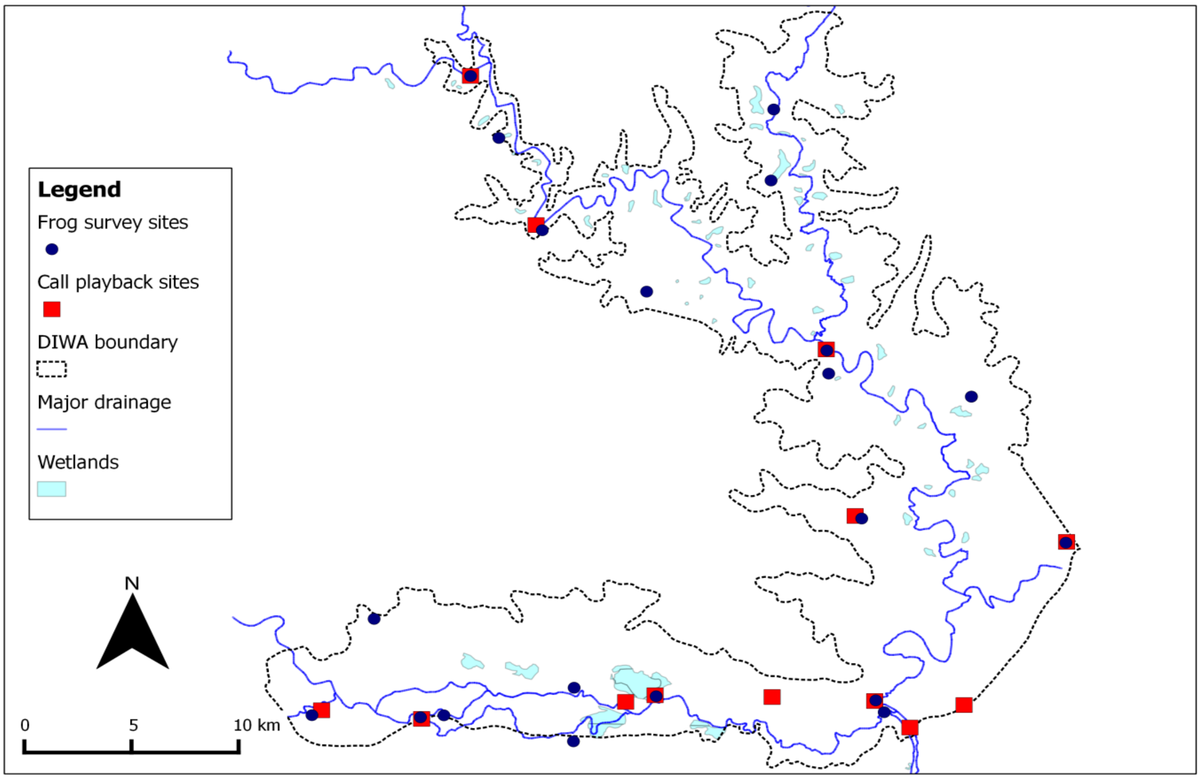


Figure 4 **Locations of frog survey sites (blue circles) and call playback sites (red squares)**

2.4.5 Bird surveys

As bird inventory was not a focus of the current survey, surveys for birds were limited to species of conservation significance and nocturnal species (*see* Nocturnal Searching and Call Playback), all other species were recorded incidentally. However, attempts were made where possible to record birds both incidentally and at survey sites. If surveys were undertaken at a trapping site, these were done during the early morning period (i.e. before 10 am). Bird species were detected by direct observation or by call. Additional bird records were collected during opportunistic searches of habitats, or via other trapping/observational methods, and in locations where alternative habitats were present (i.e. wetlands) or in potential suitable habitat for cryptic or rare species (see Appendix D).

2.4.6 Targeted searches

Targeted searches involved intensive investigation of potential shelter sites such as logs, rocks, leaf litter and rock crevices. Established trapping sites and additional opportunistic sites throughout the survey area were actively searched during the day for reptiles. Techniques used included searching beneath bark of dead trees, breaking open old logs, stumps and dead free-standing trees, over-turning logs and stones, and investigating burrows. Secondary evidence such as tracks, diggings, nests, scats and scratches were also recorded. Search duration depended on habitat complexity, whereby areas of fallen timber, rocks and debris were searched longer than the more 'simple' habitats.

2.4.7 Opportunistic searches

Additional species opportunistically observed during trap establishment, or whilst traversing the survey area, were recorded.

2.4.8 Nocturnal searches

Nocturnal searches for frogs, reptiles, birds and mammals were undertaken using a combination of high-powered spotlights and head torches. The survey area was traversed using vehicle-based road transects, on-foot opportunistic searches and spotlight searches for nocturnal species

2.4.9 Call playback

Pre-recorded calls of the Koala (DEHP 2012), Powerful Owl, Barking Owl, Masked Owl, Grass Owl (BOCA 2007a) and Bush-stone Curlew (BOCA 2007b), were used to aid the detection of these species. Call playback was undertaken at 13 sites (Figure 4), whereby recordings were broadcasted through the speakers of a vehicle. Each call was played once, followed by a 3-5 minute listening period. The surrounding area was then searched with a handheld spotlight for a further 5 minutes. If potential positive responses were heard, the recording of that particular species was repeated.

2.5 Taxonomy and nomenclature

Field identification of vertebrate species was based on the following field guides:

Mammals	Menkhorst & Knight (2001); van Dyck *et al*. (2013);
Reptiles	Wilson (2005); Wilson & Swan (2010; 2013);
Amphibians	Tyler & Knight (2011); Vanderduys (2012);
Birds	Simpson & Day (1999); Morcombe & Stewart (2010)

- In this report, nomenclature follows: Reptiles - Wilson & Swan (2013); Amphibians - Anstis (2013); Mammals - van Dyck *et al*. (2013); Bats - Armstrong & Reardon (2006); Birds - BirdLife Australia (2013).

2.6 Survey limitations

Several limiting factors were encountered that may have reduced the likelihood of recording all the species that inhabit the wetland area, these include:

- **Accessibility:** During the first phase, access was granted to 16 of the 27 leaseholds within the area. The second phase however, we were restricted to only 10 of the 27 leaseholds.
- **Weeds:** Due to the requirement of washing the vehicle clear of weeds before visiting each property, we needed to position sites close to roads so these could be accessed on foot. It would have been impossible to drive back and forth to the weeds wash down bay (~40km round trip) between sites and still have traps cleared in sufficient time.
- **Size of area/Distance to sites:** As the area is relatively large, transit time between sites was time consuming. For this reason, we could only have a limited number of trapping sites open at any given time. To combat this we split the survey area into two halves (north & south) and had two separate trapping events during October.
- **Cattle:** Presence of cattle was also a major factor. Many sites, including most wetlands had high cattle activity. This made it very difficult to trap in. We had to avoid these sites as much as possible and assess these areas through other methods (active searches etc.).
- **Weather and seasonality:** Excessive rainfall in February 2013 delayed access until late March. Overnight temperatures were getting low by this stage. October on the other hand was extremely dry, with very little animal activity.
- **Extent of habitat**: Although some very good and intact habitats persist with the area, some are quite small and patchy.
- **Trapping vs**. **active searching:** The times when traps need to be checked and optimum times for active searches begin overlapped. Opportunities may have been missed in detecting species that are possibly more detectable during the early morning (e.g. basking lizards).

3 Results

A total of 33 species of native mammal (and an additional six non-native mammal), 143 species of bird (plus one non-native species), 39 species of reptile and 14 species of amphibian (and an additional non-native species) were recorded during the survey. Of these only 6 species of amphibian, 19 species of reptile and 1 species of mammal were captured using conventional trapping methods (Table 1). All other species were detected through alternative methods. A summary of all taxa recorded are presented in Appendices C and D.

Table 1 Vertebrate fauna species and numbers captured using an array of conventional trapping techniques (Pit-fall bucket, funnel and Elliott traps) and the site number of capture

		Site											
FAMILY and Species	**Common Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
LIMNODYNASTIDAE													
Limnodynastes fletcheri	Fletcher's frog												1
Limnodynastes salmini	salmon-striped frog				1								
Limnodynastes tasmaniensis	spotted marsh frog				3								
Limnodynastes terraereginae	northern banjo frog				1							1	
Platyplectrum ornatum	ornate burrowing frog				5								
CHELUIDAE													
Chelodina longicollis	snake-necked turtle	1											
GEKKONIDAE													
Gehyra dubia	dubious Dtella	1					1						
Heteronotia binoei	Bynoe's gecko				1		1						
PYGOPODIDAE													
Pygopus schraderi	eastern hooded scaly-foot			1									
SCINCIDAE													
Anomalopus leuckhartii	two-clawed worm-skink		1										
Carlia munda	striped rainbow skink												5
Carlia pectoralis	open-litter rainbow skink		4	2			2	8					
Carlia schmeltzii	Schmeltz's rainbow skink		1										
Carlia vivax	lively rainbow skink	1				1		6		1		4	1
Cryptoblepharus pulcher pulcher	elegant snake-eyed skink									1			
Ctenotus robustus	eastern striped skink	1											
Lerista fragilis	eastern mulch slider					2				1	1		
Lerista punctatovittata	eastern robust slider			2									
Lygisaurus foliorum	tree-base litter-skink	2	1		1	1	3	1		1		1	10
VARANIDAE													
Varanus tristis	freckled monitor			1			1						
ELAPIDAE													
Cryptophis nigrescens	eastern small-eyed snake											1	
Demansia p. psammophis	yellow-faced whip snake			1	1		2		1	1			1
Furina diadema	red-naped snake												1
Pseudonaja textilis	eastern brown snake	3			1			2					
DASYURIDAE													
Planigale maculata	common planigale							1				1	
BUFONIDAE													
Rhinella marinus	cane toad	1									1		
MURIDAE													
Mus musculus	house mouse	2	1		1			3	2				

3.1 Mammals

Of the 33 native mammal species recorded, 14 species were insectivorous micro-bats, which were all recorded through acoustic detectors. An additional bat species, the Little Red Flying-fox (*Pteropus scapulatus*) was detected opportunistically. Of the 18 terrestrial mammals detected, only one native species, the Common Planigale (*Planigale maculata*) was recorded through conventional trapping methods (Table 1), with a meagre total of two captures across two sites (both in Pitfall bucket traps). All other species were either recorded through targeted and opportunistic searches, call playback sessions or by motion-sensor cameras (see Appendix C). In addition, Elliott traps failed to capture any species of native mammal. There were few captures of reptiles, with most captures being of the introduced House Mouse (*Mus musculus*). The only other species of small mammal recorded during the survey was a single Delicate Mouse (*Pseudomys delicatulus*), detected during opportunistic surveys on Gwambegwine station.

Macropods (kangaroos and wallabies) dominated the mammal, comprising of seven species, with records from targeted and opportunistic searches, motion-sensor cameras or whilst traversing the area by vehicle or on foot. Of these, the Red-necked Wallaby (*Macropus rufiogriseus*) and Eastern Grey Kangaroo (*M. giganteus*) were the most frequently observed and widespread, occurring throughout most areas and habitats. The Swamp Wallaby (*Wallabia bicolor*) was occasionally observed, with several individuals being observed in denser, intact habitats including Brigalow and She-oak woodlands. Common Wallaroos (*M. robustus*) were frequently observed in the hills and rocky habitats, whilst the Whiptail Wallaby (*M. parryi*) was only recorded from the drier woodland habitats in the North, with large groups being observed in this area. Only a single Black-striped Wallaby (*M. dorsalis*) was recorded. This was on a motion camera in remnant woodland within a lands lease reserve near Belle Eau station. In addition, one species of rock wallaby, the Herbert's Rock Wallaby (*Petrogale herberti*) was recorded, with a healthy population inhabiting a small, rocky hill on Renlew Station (Figure 5).

(A) **(B)**

Figure 5 **Isolated rock outcrops on Renlew station, one of the very few areas of rocky outcropping within the study area (A). Herbert's Rock Wallaby (*Petrogale herberti*), regularly encountered while surveying the rocky outcrop (B).**

Arboreal mammal diversity was also high, with the Common Brush-tailed Possum (*Trichosurus vulpecula*) and three species of gliding possum, the Greater Glider (*Petauroides volans*), Sugar Glider (*Petaurus breviceps*) and Squirrel Glider (*P. norfolcensis*) being detected. Most records were gathered during nocturnal spotlight searches. However, two *P. breviceps* records were initially made when an individual responded to owl call playback. In addition, two *P. volans* were recorded during the day at site 6 whilst undertaking targeted herpetofauna searches, when they were observed 'chasing' one another outside a large tree hollow.

Of the 21 separate bat detector deployment nights, 15 of these were able to have bat calls analysed, consequently only the October recordings were able to be analysed. All sites were very productive, except for trapping site 8 and the small area of rocky outcropping on Renlew station, most sites recorded between 8 and 11 species. Overall, micro-bat species diversity was extremely high, with at least 14 and as many as 18 species being detected (see Table 1 in Appendix E). The most frequently recorded and widely distributed species, with between 10 and 15 confirmed localities were *Chalinolobus gouldii*, *C. picatus*, *Nyctophilus* sp., *Scotorepens greyii*, *Mormopterus becarrii*, *Mormopterus* sp. 2 and *Saccolaimus flaviventris*. A further 5 species were moderately common with 5 to 10 confirmed localities, *Scotorepens balstoni*, *Miniopterus schreibersii*, *Tadarida australis*, *Chaerephon jobensis* and *Mormopterus* sp. 3. The two species, *Chalinolobus morio* and *Vespadelus troughtoni* were much less common, with only one and four confirmed localities respectively. In addition, the three species *C. nigrogriseus*, *V. baverstocki* and *Vespadelus vulturnus* were potentially recorded within the area, but not positively identified. *Chalinolobus nigrogriseus* however has previously been recorded at Lake Murphy Conservation Park (DEHP 2013a), and is therefore included within the species occurrence.

3.2 Reptiles

Of the 39 reptile species recorded within the survey area, only 19 species (approximately half) were recorded using conventional trapping methods, with a total of 114 captures across all 12 sites (See Table 1). All other species were either recorded through targeted and opportunistic searches, or by motion-sensor cameras, with many only recorded on a single occasion.

The most commonly encountered and widespread species were the small, diurnal leaf litter skinks such as the Rainbow Skinks (*Carlia pectoralis* and *C. vivax*) and Litter Skinks (*Lygisaurus foliorum)*. However, good numbers were only observed in areas containing a good ground layer, such as leaf-litter and wood debris (i.e. site 12), few other species were recorded in more than 5-10 individuals. Two additional Rainbow Skinks were also recorded (*C. munda* and *C. schmeltzii*), however, these were only recorded at a single locality (Sites 12 and 2 respectively). Fossorial lizards such as *Anomalopus* spp. and *Lerista* spp. were also scarce. Targeted herpetofauna surveys recorded both *Lerista fragilis* and L. *punctatovittata*, though failed to confirm any *Anomalopus* spp., trapping surveys however recorded both *Lerista* spp. and a single *Anomalopus leuckhartii*. The nocturnal gecko species *Gehyra dubia* and *Nebulifera robusta* were commonly observed during nocturnal surveys.

The Eastern Brown Snake (*Pseudonaja textilis*) and Yellow-faced Whip snake (*Demansia psammophis*) were the only two primarily diurnal snake species recorded and also the most readily encountered snake species. Several species of nocturnal snake were also recorded, but in very few numbers, with only single records of the small, nocturnal species the Red-naped Snake (*Furina diadema*), Dwyer's Snake (*Parasuta dwyeri*), and four Eastern Small-eyed Snake (*Cryptophis nigrescens*) records. Only a single Black-headed Python (*Aspidites melanocephalus*) was recorded, along with two Spotted Pythons (*Antaresia maculosa*) and three Carpet Pythons (*Morelia spilota mcdowelli*). Colubrid snakes were also rarely encountered, with only a single record of the Keelback (*Tropidonophis mairii*) and two records of the Brown Tree Snake (*Boiga irregularis*). The Common Tree Snake (*Dendrelaphis punctulata*) was not recorded during the current survey, however this has been recorded at Lake Murphy Conservation Park (Kelly 2011).

Goanna numbers were also low, with only two records of the Lace Monitor (*Varanus varius*), both from Lake Murphy Conservation Park, and three records of the Freckled Monitor (*V. tristis*). A single Yellow-spotted Monitor (*Varanus panoptes*) was also recorded.

3.3 Amphibians

A total of 14 amphibian species were recorded during the survey. Only 5 species were captured using conventional trapping techniques (Table 1), all other species were recorded during targeted and opportunistic searches, which included targeted frog surveys at 20 sites spread over 12 nights. Both the March and October surveys produced 13 species, however, the Wide-mouthed Frog (*Cyclorana novaehollandiae*) was only detected during March, while the Eastern Stony Creek Frog (*Litoria wilcoxii*) was only detected in October. Although species detections were similar between both survey seasons, numbers were much lower in October.

By far the most abundant and widespread species recorded were *Limnodynastes fletcheri*, *Litoria caerulea*, *Litoria latopalmata*, *Litoria peronii*, *Litoria rubella* and *Platyplectrum ornatum*, which appeared to be ubiquitous throughout the area. *Cyclorana alboguttata*, *Limnodynastes salmini*, *Limnodynastes tasmaniensis*, *Limnodynastes terraereginae* and *Litoria fallax* were less common, only being recorded at particular localities. The two water-holding frogs *Cyclorana brevipes* and *C. novaehollandiae* were only recorded on a few occasions, whilst *Litoria wilcoxii* was only recorded along Palm Tree Creek, however Kelly (2011) also recorded this species on Robinson Creek.

3.4 Non-native species

Seven species of non-native mammal, one species of non-native bird and one species of non-native amphibian were recorded within the survey area. These were the House Mouse (*Mus musculus*), Red Fox (*Vuples vulpes*), Feral Cat (*Felis catus*), European Brown Hare (*Lepus europaeus*), European Rabbit (*Oryctolagus cuniculus*), Pig (*Sus scrofa*), Common Myna (*Acridotheres tristis*), and the Cane Toad (*Rhinella marinus*). Horses and cattle were often observed throughout the area, but are treated as domestic as opposed non-native, feral species. Unlike many of the native frog species, the Cane Toad was infrequently observed. Only two animals were captured during the trapping program and less than 30 animals were seen active or observed calling during targeted surveys.

3.5 Conservation significant species

A total of 23 species of conservation significant species were recorded, these included two species protected under state and commonwealth legislation, eight species protected under state legislation, three species of migratory importance, and 13 species (including Koala) of regional significance (EPA 2002). These included ten bird species, nine mammal species, three reptile species and one amphibian species (Table 2).

Table 2 Vertebrate species of conservation or regional significance confirmed during the current survey.

Scientific Name	Common Name	Threat category		
		EPBC Act	NC Act	Regional Priority (Brigalow South)
Nettapus coromandelianus	cotton pygmy-goose		NT	
Ephippiorhynchus asiaticus	black-necked stork		NT	
Melitheriptus gularis	black-chinned honeyeater		NT	
Geophaps scripta scripta	squatter pigeon (Southern)	V	V	
Ninox connivens	barking owl			P
Pyhrrholaemus sagittatus	speckled warbler			P
Pomatostomus temporalis	grey-crowned babbler			P
Hirundapus caudacutus	white-throated needletail	M		
Merops ornatus	rainbow bee-eater	M		
Ardea ibis	cattle egret	M		
Phascolarctos cinereus	koala	V	V	P
Isoodon macrourus	northern brown bandicoot			P
Trichosurus vulpecula	common brush-tailed possum			P
Petaurus norfolcensis	squirrel glider			P
Petauroides volans	greater glider			P
Aepyprymnus rufescens	rufous bettong			P
Macropus dorsalis	black-striped wallaby			P
Chalinolobus picatus	little pied bat		NT	
Miniopterus schreibersii	large bent-winged bat			P
Strophurus taenicauda taenicauda	southern golden-tailed gecko		NT	
Paradelma orientalis	Brigalow scaly-foot		V	
Varanus panoptes panoptes	yellow-spotted monitor			P
Limnodynastes salmini	salmon-striped frog			P

EPBC **Environmental Protection and Biodiversity Conservation (National)**
NC **Nature Conservation (Qld)**
V **Vulnerable**
NT **Near Threatened**
M **Migratory**
P **Priority**

3.5.1 Mammals

Nine species of conservation significant mammal were recorded (See Table 2 & Figure 6). The Koala (*Phascolarctos cinereus*) was recorded at two localities, both sites being amongst tall Eucalypt woodland, in close association with Palm Tree Creek. A total of five individuals were recorded (one via opportunistic daylight searches, two during spotlight searches and a further two during call playback responses, and subsequently spot-lit). The Northern Brown Bandicoot (*Isoodon macrourus*) was detected at two sites. One individual was recorded on a motion camera at site 11, while diggings were detected at site 5. The Common Brush-tailed Possum and Greater Glider were much more common throughout the area, being recorded in many of the treed habitats, particularly along riparian zones or where larger trees persisted, unlike the Squirrel Glider with only single record, observed during a nocturnal spotlight survey at site 12. The Rufous Bettong (*Aepyprymnus rufescens*) appeared to be in healthy numbers, particularly in the open grassy woodlands of Broadmere and Robinson Creek stations. These were generally encountered during nocturnal walking or vehicle-based surveys, though several were captured on motion cameras. The Black-striped wallaby (*Macropus dorsalis*) was also recorded, but only at one locality near Belle Eau station, captured on a motion camera. The two bat species, Little Pied Bat (*Chalinolobus picatus*) and Large Bent-winged Bat (*Miniopterus schreibersii*) were recorded across much of the study area, particularly in association with the Robinson and Palm Tree creeks and associated tributaries (Figure 7).

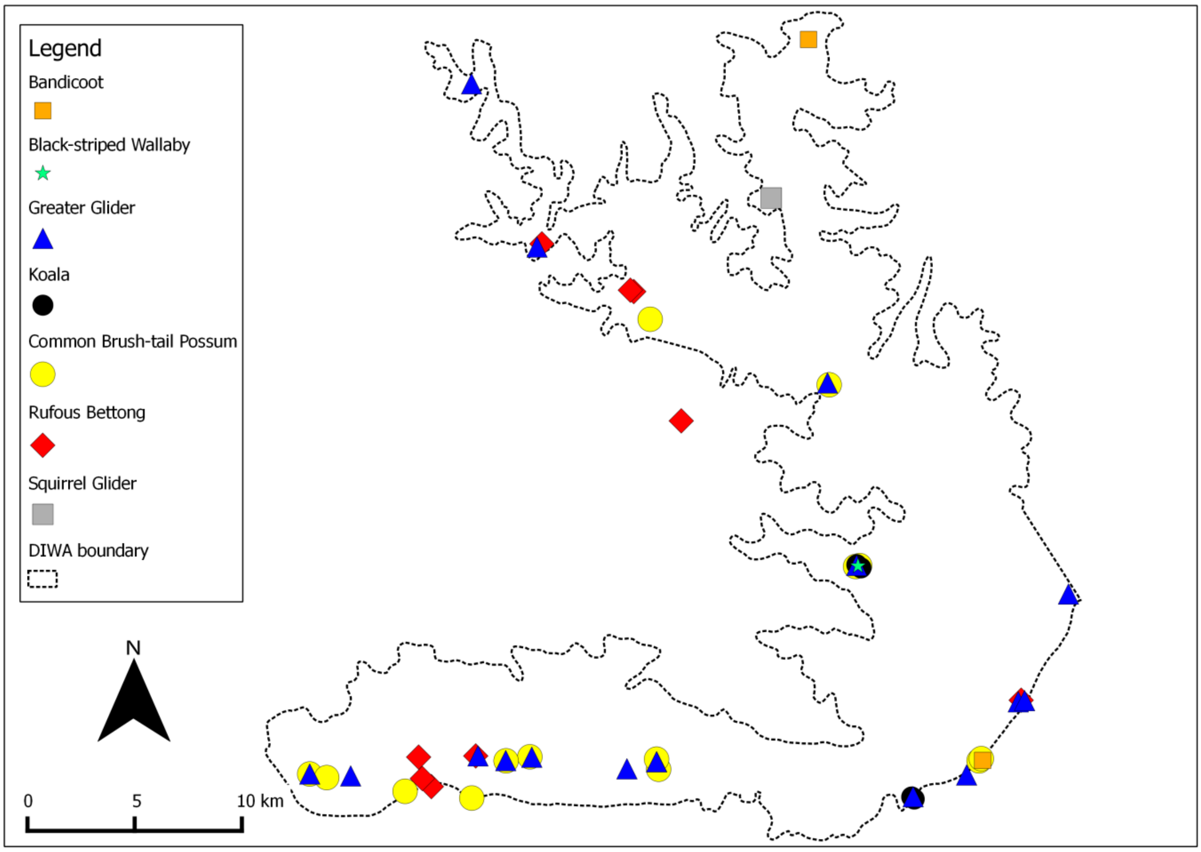


Figure 6 Localities where conservation and regionally significant mammals were recorded.

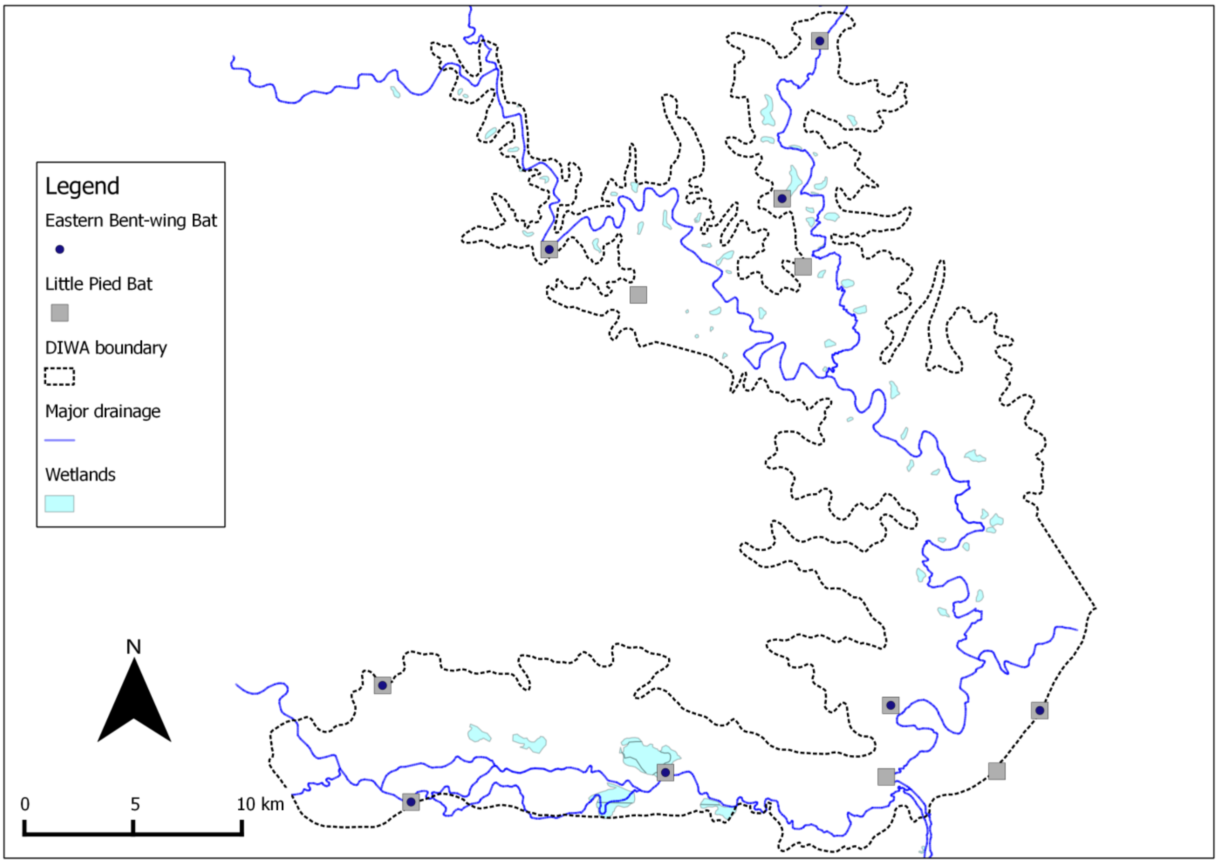


Figure 7 Localities where the two significant bat species, Little Pied Bat (*Chalinolobus picatus*) and Eastern Bent-wing Bat (*Miniopterus schreibersii*) were recorded.

3.5.2 Birds

In total, 143 bird species were recorded, including 10 confirmed species of conservation significance (Table 2 and Figure 9; see also Appendix D). Of these, the Barking Owl was observed on two occasions, both during call playback sessions and in close proximity to *Livistona* woodlands along Palm Tree Creek. The Cotton Pygmy-goose was only observed at a large, well-vegetated wetland on Jamberoo station, where four individuals were observed. The Black-necked Stork was observed at three locations (presumably three individuals), Lake Murphy Conservation Park, Waunui Station (Figure 8) and another individual observed in flight along the Fitzroy Developmental Road. Three Squatter Pigeons were also recorded during the March surveys, however, none were seen in October and all records were from the northern part of the survey area. Only two Speckled Warblers were recorded, both from Renlew Station on an outlying rocky hill. Lake Murphy Conservation Park was the only area we recorded the Black-chinned Honeyeater, which was also only one of three localities where Grey-crowned Babblers were observed. The migratory Rainbow Bee-eater was recorded at multiple locations throughout the site, as well as several records of Cattle Egrets and a single record of the White-throated Needle-tail. The Powerful Owl was also potentially recorded during a call playback attempt. A single, possible response was heard some distance away during a call play back session near Belle Eau station. Further attempts to call in the individual proved unsuccessful. Subsequent call playback attempts were made in the vicinity during successive nights, though no further response was detected. The Powerful Owl however, has been confirmed at Lake Murphy Conservation Park (Kelly 2011), it is therefore likely to be present across the wider area.

Figure 8 **The Near-threatened Black-necked Stork foraging near an artificially fed water body on Waunui station.**

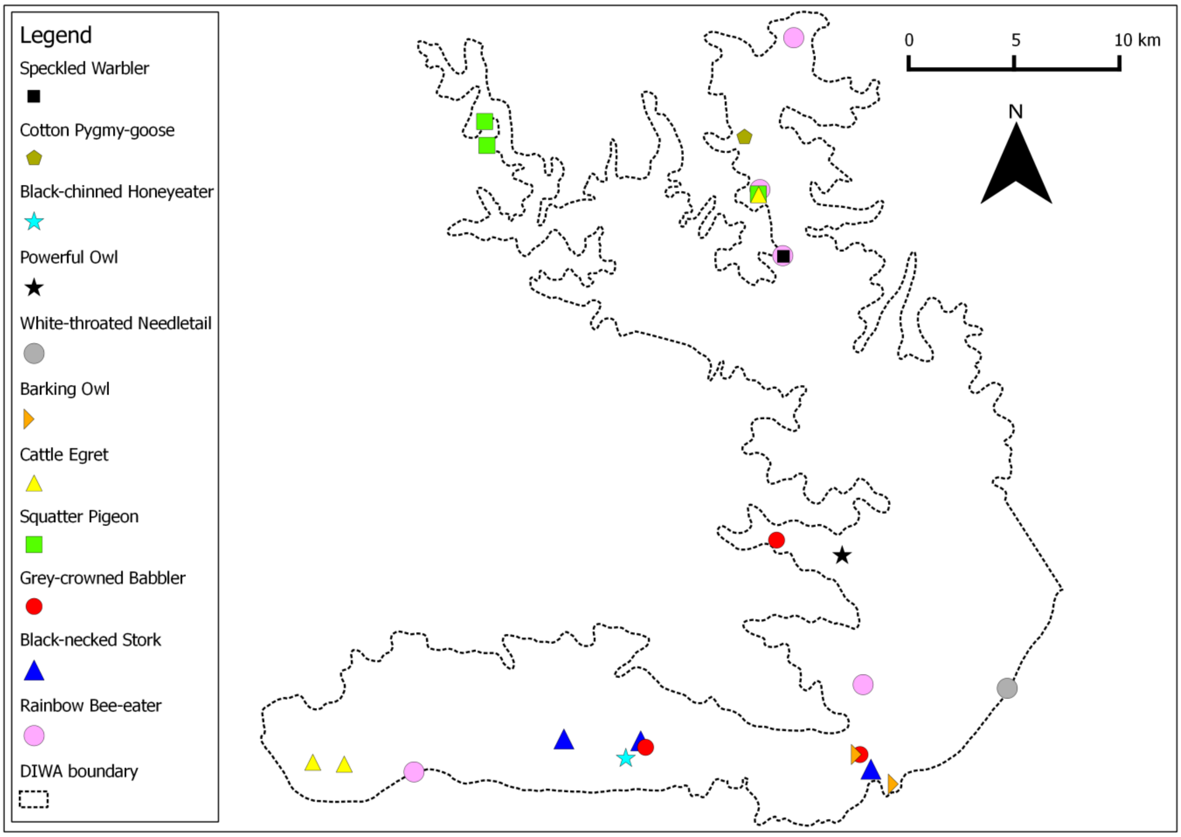


Figure 9 **Localities where conservation or regionally significant bird species were recorded.**

3.5.3 Herpetofauna

Three species of conservation significant reptile were recorded during the current survey (Table 2 and Figure 11). The Brigalow Scaly-foot (*Paradelma orientalis*) was recorded at two localities. One individual was found beneath a large, embedded log amongst intact Eucalypt/Brigalow woodland in a lands lease reserve near Belle Eau station (Figure 10), the other record was a recent skin slough found beneath a log on Bloomfield station. The Southern Golden-tailed Gecko (*Strophurus taenicauda taenicauda*) was recorded from six localities with 14 individuals, most being from areas with dense coverage of *Callitris glaucophylla* and *Casuarina cristata* (i.e. Sites 3, 5 and 8). Only a single Yellow-spotted Monitor was recorded. This came from a motion-camera at Site 10 on Jamberoo station. Several large goanna tracks were also recorded throughout this particular site (presumably from the same individual).

Figure 10 The state listed Vulnerable Brigalow Scaly-foot (*Paradelma orientalis*) recorded from near Belle Eau station.

The only significant species of amphibian recorded during the survey was the regionally significant Salmon-striped Frog (*Limnodynastes salmini*). Only a handful of observations were made of this species across four sites. All records were in areas associated with ephemeral wetlands on alluvial soils in the South of the study area.

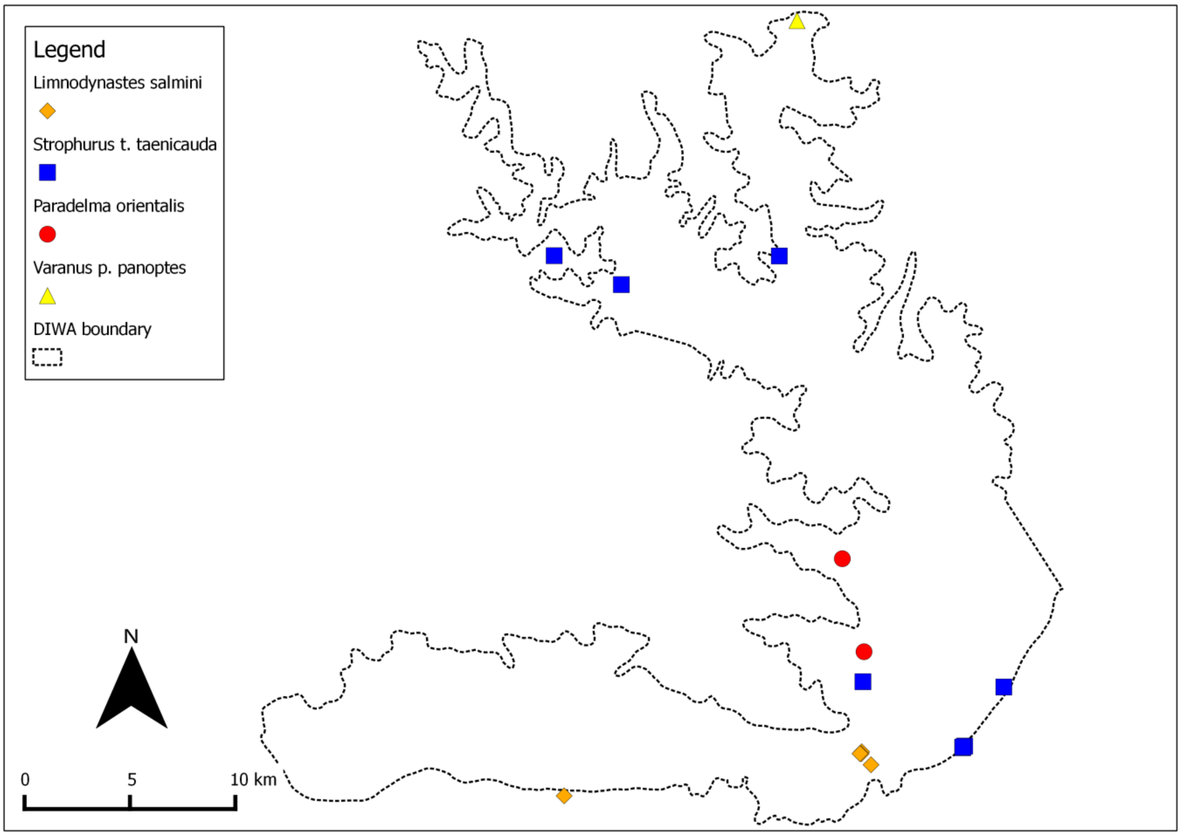


Figure 11 **Localities where reptiles and amphibians of conservation or regional significance were recorded.**

3.6 Additional species

In addition to the species recorded during the current survey, a recent survey of the Lake Murphy Conservation Park (within the DIWA study area) recorded an additional six species of native animal: The Water Rat (*Hydromys chrysogaster*), Eastern Chestnut Mouse (*Pseudomys gracilicaudatus*), Broad-shelled Turtle (*Chelodina expansa*), Three-clawed Worm-skink (*Anomalopus verreauxii*), Common Tree Snake (*Dendrelaphis punctulata*) and Eastern Sign-bearing Froglet (*Crinia parinsignifera*) (Kelly 2011), including an additional species of regional significance, the Broad-shelled Turtle. The Delicate Skink (*Lampropholis delicata*) is also known to occur at Lake Murphy Conservation Park (Queensland Museum specimen), as also is the Hoary Wattled Bat (*Chalinolobus nigrogriseus*) (DEHP 2013a). These additions increase the known number of native vertebrates (excluding birds) known to occur within the area to 94 species.

4 Discussion

4.1 Fauna habitats

4.1.1 Riparian

Many areas along Palm Tree Creek and Robinson Creek and their associated tributaries contained many large, hollow bearing trees. These provided excellent habitat for many species of arboreal marsupial such as Greater Gliders and Common Brush-tail Possums. It was in these habitats where species such as the Koala and Northern Brown Bandicoot were also recorded. The degree of riparian vegetation varied from sparse, open Eucalypt woodland (e.g. Broadmere station area) through to Eucalypt woodland with a dense, grassy understory (e.g. Jamberoo station area). Parts of the Robinson and Palm Tree Creeks at Lake Murphy Conservation Park and Palm Vista station also contained dense *Livistona* woodlands. Areas such as these were where Barking Owls were recorded, and is also a known locality of the Powerful Owl (Kelly 2011).

Figure 12 Riparian vegetation near site 7 along Robinson Creek.

4.1.2 Eucalypt woodlands with shrubs

Much of these habitats contained large Eucalypts with a mixture of shrubs including *Acacia harpophylla*, *Casuarina cristata* and *Callitris glaucophylla*, often with a dense ground layer of grasses, leaf litter and woody debris. The most intact areas were in the vicinity of Belle Eau, Bloomfield and Box Tree stations. The Gwambegwine station area also contained good areas of dense shrubbery. Areas such as these were important habitats, providing thick cover for the Brigalow Scaly-foot, Southern Golden-tailed Gecko, Black-striped Wallaby and Rufous Bettong. Other species potentially occurring in these habitats include the Yakka Skink and Dunmall's Snake (*Furina dunamalli*), which unfortunately were not confirmed during the current survey.

Figure 13 Eucalypt woodland with a shrubby understorey at site 6.

4.1.3 Eucalypt woodlands with grassy understorey

This habitat was widespread through the study area. However, many areas, particularly around wetlands had been fairly heavily impacted by grazing. Areas such as these had poor grassy understorey and very little leaf-litter and ground debris coverage. Protected areas such as Lake Murphy Conservation Park (Figure 14) contained good quality Eucalypt woodlands with a thick grassy understorey. Areas such as these probably create suitable habitat for a range of species that were infrequently recorded during the survey (e.g. *Ctenotus robustus*). It is also habitat for species that were not recorded during the current survey, but have been recorded previously such as the Eastern Chestnut Mouse (*Pseudomys gracilicaudatus*) (Kelly 2011) which relies strongly on certain densities of ground vegetation, usually a considerable time after fire (Fox 2008). The Black-chinned Honeyeater was also only recorded in this habitat at Lake Murphy Conservation Park.

Figure 14 Eucalypt woodland with a dense grassy understorey at Lake Murphy Conservation Park.

4.1.4 Rocky outcrops

There were few areas of rocky outcrops recorded within the survey area. Parts of Gwambegwine and Jamberoo stations contained some low rocky hills and outcrops, Renlew station however contained a large rocky outcrop (Figure 15), sparsely connected to a larger rocky range to the West. This area potentially provides habitat for significant species such as the Brigalow Scaly-foot, Yakka Skink and Northern Quoll (*Dasyurus hallucatus*). Although these species were not detected at this site (the latter two not detected at all), the Speckled Warbler and Herbert's Rock Wallaby were recorded from here, which were both detected nowhere else during the survey.

Figure 15 **Rocky outcropping on Renlew station.**

4.1.5 Wetlands

Many of the wetland environments visited during the survey period housed good diversity of fauna, notably bird and frog species. It was clear however, that the deeper, more permanent wetlands such as those at Lake Murphy Conservation Park, Jamberoo (Figure 16), Lakefield and Wythburn stations contain good species diversity, particularly waterbirds. These sites, although grazed, also have good vegetation coverage around the perimeters, providing cover for dependent species such as frogs and possibly support species such as the Grey Snake and Ornamental Snake.

Figure 16 **Large, deep wetland on Jamberoo station. This particular site was surrounded by many large, hollow-bearing trees and extensive log cover around the perimeter. The Cotton Pygmy-goose was also observed in good numbers here.**

4.2 Conservation significant species accounts

Below are brief accounts of species either listed as threatened or of regional significance recorded during the survey, outlining their occurrence, habitat preferences and potential threats.

4.2.1 Koala (Phascolarctos cinereus)

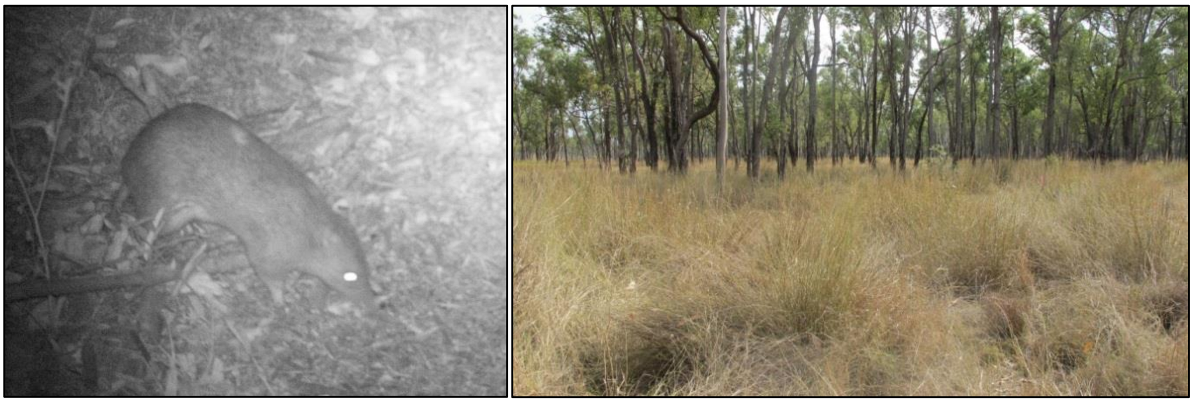
Listed as Vulnerable under commonwealth and state legislation, the Koala is patchily distributed throughout eastern Australia, where it is primarily associated with Eucalypt woodlands. Further inland, Koalas are more restricted to waterways, where records are often associated with well-vegetated, riparian corridors lined with River Red Gums (Martin *et al.* 2008). Threats to the Koala include a combination of habitat modifications such as clearing and fragmentation, intense canopy fires, and predation particularly from feral and domestic dogs, may be an issue (Martin & Handasyde, 1999). The current survey recorded the Koala at two sites, both in close association with Palm Tree Creek and/or extensive, intact Eucalypt woodland. Potential habitat exists along many parts of both Palm Tree and Robinson Creeks and their associated tributaries, and the Koala is predicted to utilise much of this area. However, the riparian habitats are heavily fragmented and dissected by farmland and discontinuous corridors such as these, may have increased exposure to predators.

(A) (B)

Figure 17 **One of five Koalas (*Phascolarctos cinereus*) observed during the survey (A). This individual observed sleeping amongst the high branches of a Eucalypt tree during the day. Habitat of the koala from within a lands lease reserve near Belle Eau station dominated by large Eucalypts (B).**

4.2.2 Northern Brown Bandicoot (Isoodon macrourus)

Generally common and widespread throughout parts of its range, the Northern Brown Bandicoot is of regional significance within the Southern Brigalow Belt bioregion (EPA 2002). It occurs in a range of grassland, woodland and open forest environments, where it favours areas of low ground-cover, including tall grass and dense shrubs. As with the koala, its inland distribution is more prevalent along riparian zones. Most notable declines have been observed in cleared areas and pastoral land, where habitat and food supplies are destroyed or depleted (Gordon 2008). Other major threats also include fire and drought. Bandicoots were uncommon in the area, with only two records. These were associated with areas of dense grassland in riparian areas, or with dense shrubbery within large blocks of intact woodland. It is anticipated that the Northern Brown Bandicoot will be more widely distributed within the area, however, it may be tightly restricted to densely vegetated riparian corridors and larger blocks of remnant woodland.



(A) (B)

Figure 18 Northern Brown Bandicoot (*Isoodon macrourus*) captured on a motion camera amongst dense riparian vegetation at site 11 (A). Riparian habitat along a tributary of the Palm Tree Creek on Jamberoo station.

4.2.3 Common Brush-tailed Possum (Trichosurus vulpecula)

Although widespread and locally abundant throughout much of Australia, the regionally significant Common Brush-tailed Possum has experienced significant population declines in parts of eastern Australia (Kerle and How 2008). Occurring in a range of dry Eucalypt forests and woodlands, it is dependent on intact habitat supporting large, hollow-bearing trees. Threats include predation by introduced species, habitat fragmentation, and loss of tree hollows associated with fires of high intensity. Although this species was recorded in good numbers, preferred habitat is patchy and animals were only recorded where areas of large, hollow-bearing trees persisted. The highest densities were observed in the riparian woodlands along Robinson Creek and Lake Murphy Conservation Park, though several observations were made along Palm Tree Creek, in roadside corridors and within intact woodland away from the creeks such as Site 5.

(A) (B)

Figure 19 **Common Brush-tailed Possum (*Trichosurus vulpecula*) recorded at site 5 (A). Eucalypt woodland surrounding a wetland on Lakefield station, the Squirrel Glider (*Petaurus norfolcensis*) was only recorded from here (B).**

4.2.4 Squirrel Glider (Petaurus norfolcensis)

The regionally significant Squirrel Glider is a small to medium-sized, gliding possum inhabiting dry sclerophyll forests. It is primarily dependent on intact, forested areas containing hollow-bearing trees, which provide hollows for nesting sites (van der Ree and Suckling 2008). Threats such as habitat clearing, inappropriate fire regimes and feral predators have contributed to declines across parts of its range. Potential habitat persisted throughout many parts of the study area, however only one individual was confirmed. This was in tall, gum-barked Eucalypt woodland surrounding a large wetland on Lakefield station. Records are also known from Lake Murphy Conservation Park (Kelly 2011).

4.2.5 Greater Glider (Petauroides volans)

The largest of Australia's gliding marsupials, the regionally significant Greater Glider inhabits a variety of vegetation types from tall forests to low woodlands. Greater Gliders have very small home ranges and are dependent of mature forest with tree hollows (McKay 2008). The main threats to this species are clearing and logging of habitat, inappropriate fire regimes and potential feral predators. The Greater Glider was recorded in high densities, particularly in riparian woodlands along Palm Tree and Robinson Creeks. Although they are predominantly solitary by nature, it was not uncommon to observe multiple individuals in the one tree or high densities within a small area (e.g. Lake Murphy Conservation park campground). This may be a direct result of the presence of high densities of large hollow bearing trees.

(A) (B)

Figure 20 **Greater Gliders (*Petauroides volans*) observed at Lake Murphy Conservation Park. Typical 'lighter' colour form (A) and unusual 'grey' colour form (B).**

4.2.6 Rufous Bettong (Aepyprymnus rufescens)

The regionally significant Rufous Bettong occurs throughout eastern Australia, where unlike many other bettong-like animals of similar size, populations seem to thrive in some areas. Inhabiting a variety of dry open woodlands, it prefers areas with a dense grassy understorey, where they can be locally abundant (Dennis and Johnson 2008). Threats include habitat modification through agricultural practises, altered fire regimes, invasive weeds and rabbits. In addition, feral predators such as cats and foxes are a significant threat. Rufous Bettongs have a tendency to travel large distances during the night (Dennis and Johnson 2008), this may increase their exposure to feral predators, particularly if dense cover is sparse. The Rufous Bettong was often observed during nocturnal surveys, and often with multiple individuals seen within a very small area. However, most records were in close association with intact habitat such as the riparian woodland and grassy flats along Robinson Creek and woodlands with a dense grassy understorey such as sites 6 and 8.


(A) (B)

Figure 21 **The Rufous Bettong (*Aepyprymnus rufescens*) was readily observed during nocturnal surveys, particularly in open, grassy woodlands near Broadmere and Robinson Creek stations (A and B).**

4.2.7 Black-striped Wallaby (Macropus dorsalis)

The regionally significant Black-striped Wallaby is a shy, habitat specialist, dependent on large tracts of woodland with dense shrubby thickets adjacent to grassy foraging areas. Due to its secretive nature, it relies on these areas, whereby it will shelter during the day in thick undergrowth and forage at night in the adjacent grassy areas, rarely moving far from dense cover. Once widespread and relatively common, it has declined over much of its range due to habitat clearing and modification (Johnson 2008). Threats such as loss of preferred habitat through clearing, inappropriate fire regimes, grazing by rabbits and livestock have been associated with declines. Introduced predators, including feral and domestic dogs, may also play a large role. The sole record of this species was from a remnant, unburnt patch of Eucalypt woodland on a lands lease reserve near Belle Eau station. This area also supported Koalas and the Brigalow Scaly-foot, and had good coverage of dense grasses and shrubby vegetation.


(A) (B)

Figure 22 **A sole record of the Black-striped Wallaby (*Macropus dorsalis*) from a motion sensor camera (A). Habitat of the Black-striped Wallaby near Belle Eau station, note the dense grass cover (B).**

4.2.8 Little Pied Bat (Chalinolobus picatus)

The state listed Near Threatened Little Pied Bat is regarded as an arid to semi-arid species, extending into the dryer areas of southern Queensland, mostly west of the Great Dividing Range were it favours Brigalow and Eucalypt woodlands and open forests (Churchill 1998). Although roosts are primarily associated with caves and rock shelters, this species also utilises hollow trees. Tree hollows are particularly important in areas such as the Palm Tree and Robinson Creek area as rocky habitats are scarce, and this species is more dependent on riparian vegetation in dryer habitats. Threats to this species include the clearing of tree hollows, grazing pressures and inappropriate frequent fire regimes (Environment Australia 1999). This species was detected at all bat detector sites within the area, suggesting that high quality habitat (probably in the form of large, hollow bearing trees) exists within the study site.

4.2.9 Large Bent-winged Bat (Miniopterus schreibersii)

Unlike *C. picatus*, the regionally significant Eastern Bent-wing Bat does not generally inhabit the arid zone, and is generally found on the coastal side of the Great Dividing Range (Churchill 1998). Eastern Bent-wing Bats roost in caves, but also in artificial structures such as road culverts, and forage widely throughout woodlands, forests and grasslands (Churchill 1998). This species was detected at 8 of the 15 analysed bat detector sites, all of which may have travelled from nearby caves in the surrounding landscape to forage in the area. This bat in particular can travel large distances (Churchill 1998). Threats to this species possibly include disturbances to caves, predation by cats and foxes (Hoye and Hall 2008 as *Miniopterus schreibersii oceanensis*) and destruction of surrounding habitats through vegetation clearing and wildfire (Environment and Heritage 2012).

4.2.10 Southern Golden-tailed Gecko (Strophurus t. taenicauda)

Although being the most widespread sub-species of the Golden-tailed geckos, it is restricted mainly to the Brigalow Belt bioregion, in particular where Cypress Pine forests dominate (Wilson & Swan, 2013), where it utilises hollow limbs and loose bark as shelter sites (Richardson 2008). Near-threatened in Queensland under state legislation, threats facing this species are predominantly habitat clearing, inappropriate fire regimes and inappropriate roadside management (Richardson 2008). Within the Palm Tree and Robinson Creek wetland area, it was observed in good numbers where patches of intact habitat persisted. Although many areas of preferred habitat have experienced selective logging or clearing, individuals were reliably detected where dense thickets of *Callitris* and *Casuarina* occurred. Higher densities were recorded within remnants on Bloomfield, Box Tree, Gwambegwine and Renlew stations.

(A) (B)

Figure 23 **The remarkably patterned and Near Threatened Southern Golden-tailed Gecko (*Strophurus taenicauda taenicauda*) from Gwambegwine station (A). Typical habitat of the Southern Golden-tailed Gecko on Box Tree station, with large stands of *Callitris* sp., *Casuarina* sp. and mixed shrubs (B).**

4.2.11 Brigalow Scaly-foot (Paradelma orientalis)

Listed as Vulnerable under state legislation, the Brigalow Scaly-foot is largely restricted to the Southern Brigalow Belt (Wilson 2003). It occurs in a variety of woodland habitats with dense ground cover, where it shelters beneath rocks, logs and dense leaf litter (Wilson & Swan 3013). Loss of habitat, possible grazing effects, inappropriate fire regimes and feral animals are the major threats to the Brigalow Scaly-foot (Richardson, 2008). Within the Palm Tree and Robinson Creek area, large tracts of suitable habitat may have already been cleared and modified within the area, however small remnants still exist. A single individual was found beneath a log in a lands lease reserve near Belle Eau station, an area that is largely intact. Similarly, a skin slough was found under a log within an intact strip of Brigalow woodland adjoining Bloomfield station, an area that was also in relatively good condition, with excellent coverage of logs and leaf-litter.

(A) (B)

Figure 24 **Remnant Brigalow (*Acacia harpophylla*) woodland on a lands lease reserve near Belle Eau station (A). A recent skin slough from *P. orientalis* found beneath a log with dense leaf-litter on Bloomfield station (B).**

4.2.12 Yellow-spotted Monitor (Varanus p. panoptes)

The regionally significant Yellow-spotted Monitor occurs throughout much of Queensland in a variety of woodland and riverine habitats (Wilson & Swan 2013). This species has undergone population declines throughout parts of its range, the most recent being in the Top End of the Northern Territory with the onset of the Cane Toad (*Rhinella marinus*) (Ward *et al*. 2012). Possible contributing factors to poor detection in the current survey may include a combination of factors including the Cane Toad, habitat destruction (depleting food sources) and possible egg predation by feral pigs.

(A) **(B)**

Figure 25 **A single Yellow-spotted Monitor (*Varanus panoptes*) captured on a motion camera within woodland with sandy soils on Jamberoo station in the far North of the study site (A and B).**

4.2.13 Salmon-striped Frog (Limnodynastes salmini)

The regionally significant Salmon-striped Frog is a member of the 'marsh-frog' family where it is primarily associated with woodland, especially cypress pine forests, swamps and billabongs (Vanderduys 2012). A characteristic of this group is its dependency of swamp and marsh type environments and also its tendency to spend significant time buried under the soil or underground debris during unfavourable conditions (Cogger 2000). The species has experienced possible declines across its range, particularly in the South-east Queensland bioregion. Threats include the destruction of woodlands, particularly cypress pine forests. Damage to wetland environments caused by livestock and feral pigs may also be contributing factors. Increased droughts associated with these areas may also play a role. Few observations were made of this species during the survey, with most being associated with ephemeral wetlands in the South of the study area.

(A) (B)

Figure 26 **(A) The regionally-significant Salmon-striped Frog (*Limnodynastes salmini*). (B) *Eucalyptus coolabah* woodland surrounding a small, ephemeral wetland (dry) near Palm Vista station, one of the few habitats where *L. salmini* was recorded.**

4.3 Threatening processes

The key threatening processes identified during the survey include the following:

- Feral animals;
- Weeds;
- Inappropriate fire regimes;
- Loss of habitat (clearing, logging and fragmentation);
- Grazing; and
- Drought.

There were a high number of feral species recorded during the survey, in particular pigs, feral cats and foxes. Pigs however, appeared the most prevalent. Pigs were recorded in many of the wetland habitats and presented a range of potential threats including habitat destruction and potential nest predation. Cats and foxes also pose a serious risk of predation. Only a single record was made of a dingo/feral dog. There may also be some predatory risks associated with these, particularly for such as the koala. Management of dingos/feral dogs however may need some careful planning, as controls causing a drop in numbers of a large predatory animal such as the dingo can cause pig numbers to increase (Woodall 1983). The cane toad, although not recorded in great numbers, may also pose a serious threat to susceptible wildlife. Rabbits were also observed in high densities, particularly in sandy areas associated with Palm Tree Creek, whilst hares were more prevalent on the alluvial soils associated with the Robinson Creek.

(A) (B)

Figure 27 **The dingo/feral dog was uncommon, with a sole individual being captured on a motion camera (A). The feral cat however was much more prevalent, with several records made from motion cameras (B), or opportunistically throughout the area. Both these species are potentially significant predators within the area and may pose a range of threats.**

(A) (B)

Figure 28 **A large, deep wetland on Jamberoo station, supporting dense vegetation and water-lilies. Photo A was taken in the wet season, while photo B, although taken in the dry season, shows the extensive damage from feral pigs. This area was also grazed by livestock.**

Although threats posed by feral species may be significantly high, the largest threats potentially are habitat loss, inappropriate fire regimes and agriculture. Much of the area has been cleared for grazing, with remnant areas being left as 'islands' with few corridors linking these up. Remnants such as these are where species such as the Koala or Brigalow Scaly-foot were recorded. These species in particular and potentially other significant species not recorded during the current survey (i.e. Common Death Adder - *Acanthophis antarcticus* and *Egernia rugosa),* are extremely susceptible to clearing and fire (Richardson 2008).

At present, many of the wetland areas and some remnant areas are also grazed by cattle. It is clear that cattle also have a negative impact, similar to pigs, whereby peripheral and emergent vegetation is destroyed and soil structures modified. Cattle however, may also play a role in keeping weed infestations down (e.g. Buffel grass), in turn controlling potential fuel levels. This again will require careful management decisions, as removal of cattle from areas may result in a high recruitment of unfavourable weed species or dominant species, possibly creating more fuel loads leading to more high intensity fires.

(A) (B)

Figure 29 **An example of a thick leaf-litter mat at the base of a Brigalow tree within an intact area of Brigalow woodland (A). Areas such as these are important habitats for many species of reptile, including the Brigalow Scaly-foot, but are extremely susceptible to fire. Large wood and debris piles (B) are also important habitat requirements for many species, particularly the Yakka Skink, which construct burrow systems underneath these (Richardson 2008).**

5 Recommendations

In summary, the Palm Tree and Robinson Creeks area contains a very high diversity of species, in particular mammals, including a high diversity of insectivorous micro-bats. Many of the species detected during the survey rely on key habitat characteristics, often with low fire history, such as areas with many trees, dense leaf litter and ground debris, thick grassy understory and habitat connectivity. The key areas of habitat existing throughout the area appear to be those with large, hollow bearing trees such as the riparian corridors and also remnant woodlands which have had a good fire history such as site 6. Also intact areas of Brigalow woodland such as the lands lease reserve and Belle Eau station through to Bloomfield station are extremely important. This area appears to have experienced little disturbance from fire and grazing impacts, and contains extensive habitat for many species of conservation significant fauna such as the Brigalow Scaly-foot.

In addition, the wetland habitats are equally important for providing resources such as habitat and food for a range of species. The main impacts observed in these areas are the degradation of fringing vegetation and soil compaction from livestock and feral pigs. Here the large hollow-bearing trees may be of high importance for many water-bird species, in particular the Cotton Pygmy-goose, which requires tall, hollow-bearing trees around the water's edge for nesting and roosting sites (Kelly 2011).

In protecting existing habitats within the area, the following should be taken into consideration:

- Avoid or minimise any clearing of native vegetation, in particular those areas that provide some connectivity between existing remnants such as riparian and roadside corridors or fence lines. Areas such as these however should be carefully managed, as inappropriate management may also result in negative impacts to species reliant on these habitats.
- Protect and maintain mature Eucalypts, particularly large, hollow bearing individuals such as those fringing wetland environments (i.e. *E. camaldulensis* and *E. tereticornis*). These appear to provide roosting and nesting sites for a range of species and also provide connectivity between remnant blocks.
- Protection of wetland areas, particularly those with high conservation value. This will include removal of and/or fencing off cattle. The removal of cattle should also be of consideration within remnant woodland areas.
- Fire management for the protection or enhancement of particular areas.
- Weed management, particularly buffel grass.
- Feral animal management, in particular feral pigs, cats and foxes.
- Protect existing corridors and enhance for future corridors. This includes roadside corridors.
- Implement plans and promote education with the local community and landholders of the awareness of and need to manage fauna, particularly those of conservation significance. If possible, implementation of protection zones may be provided for remnants on private land.

In addition, future follow-up and targeted surveys will also be an important aspect. The survey failed to detect several species of high conservation significance, including the Northern Quoll (*Dasyurus hallucatus*), Grey Snake (*Hemiaspis daemelii*), Dunmall's Snake (*Furina dunmalli*), Ornamental Snake (*Denisonia maculata*) and Yakka Skink (*Egernia rugosa*). All these species except *H. daemelii* are listed as Vulnerable under commonwealth legislation and with the possible exception of *D. hallucatus* and *D. maculata*, are all a very high probability of occurring in the area.

Unfortunately in the current survey, overnight conditions in March were relatively cool, whilst overall conditions during October were very dry. Conditions such as these don't often produce good activity of nocturnal snake species that rely on warmer, wetter conditions (pers. obs.). For this reason, it is highly recommended that follow up surveys be undertaken when conditions are more suitable for species such as these. In particular for species such as *H. daemelii* and *D. maculata*, that are reliant on the deep, cracking soils in wetland and floodplain environments, as disturbances and compaction of soil associated with pasture and grazing observed in wetland and floodplain environments is of serious threat to these species (Richardson 2008). In addition, *E. rugosa* relies strongly on large, intact areas of Brigalow and Eucalypt woodland (Richardson 2008). Continued fragmentation, grazing and potential intense fires could also have detrimental effects on this species if it currently occurs in the area. There is a high probability that the species occurs in the open, forested areas in the North of the study site, and the intact Brigalow and Eucalypt woodlands in the central and southern areas. Although targeted surveys failed to detect this species on Box Tree, Bloomfield and Jamberoo stations, the species may still occur there and also possibly on other leasehold properties such as Gwambegwine and Belle Eau.

Finally, access to many parts of the area were denied during the current survey, particularly during the trapping phase. Unfortunately we were unable to conduct trapping and intense surveys on many properties where potential suitable habitat existed. Hopefully some of these properties will be able to have surveys undertaken on them in the near future.

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7 Appendices

Appendix A – Species of conservation or regional significance with likelihood of occurrence

Scientific Name	Common Name	Threat category			Likelihood of Occurrence (excluding diurnal birds)	Current Survey	Kelly (2011)	^QM	^DEHP (2013b)
		EPBC Act	NC Act	Regional Priority (Brigalow South)					
Birds									
Apus pacificus	Fork-tailed Swift	M			-			-	-
Nettapus coromandelianus	Cotton pygmy-goose		NT		-	x	x	-	-
Burhinus grallarius	Bush-stone Curlew			P	Likely			-	-
Ephippiorhynchus asiaticus	Black-necked stork		NT		-	x	x	-	-
Melitheriptus gularis	Black-chinned honeyeater		NT		-	x		-	-
Geophaps scripta scripta	Squatter pigeon	V	V		-	x		-	-
Ninox connivens	Barking owl			P	Likely	x		-	-
Ninox strenua	Powerful Owl		V		Known	?	x	-	-
Tyto novaehollandiae	Masked Owl			P	Likely			-	-
Tyto capensis	Grass Owl			P	Possible			-	-
Climacterius picumnus	Brown Treecreeper			P	-			-	-
Erythrotriochis radiatus	Red Goshawk	V	E		-			-	-
Accipiter novaehollandiae	Grey Goshawk		NT		-			-	-
Heliaeetus leucogaster	White-bellied Sea-eagle	M			-		x	-	-
Pandion haliaetus	Osprey	M			-			-	-
Lathamus discolor	Swift Parrot	E	E		-			-	-
Myiagra cyanoleuca	Satin Flycatcher	M			-			-	-
Monarcha melanopsis	Black-faced Monarch	M			-			-	-
Rhipidura rufifrons	Rufous Fantail	M			-			-	-
Melanodryas cucullata	Hooded Robin			P	-			-	-
Neochima ruficauda ruficauda	Star Finch (eastern)	E	E		-			-	-
Rostratula australis	Australian Painted Snipe	E	V		-			-	-
Poephila cincta cincta	Black-throated Finch	E	E		-			-	-
Stagonopleura guttata	Diamond Firetail			P	-			-	-
Turnix melanogaster	Black-breasted Button-quail	V	V		-			-	-
Pyhrrholaemus sagittatus	Speckled warbler			P	-	x		-	-
Pomatostomus temporalis	Grey-crowned babbler			P	-	x	x	-	-
Pomatostomus superciliosus	White-browed babbler			P	-			-	-
Hirundapus caudacutus	White-throated needletail	M			-	x		-	-
Merops ornatus	Rainbow bee-eater	M			-	x		-	-
Ardea alba	Great Egret	M			-			-	-
Ardea ibis	Cattle Egret	M			-	x		-	-
Gallinago hardwickii	Latham's Snipe	M			-			-	-
Anseranas semipalmata	Magpie Goose	M			-			-	-
Mammals									
Ornithorhynchus anatinus	platypus			P	Unlikely				
Phascolarctos cinereus	koala	V	V	P	Likely	x		x	x
Isoodon macrourus	northern brown bandicoot			P	Likely	x		x	
Perameles nasuta	Long-nosed bandicoot			P	Unlikely				
Trichosurus vulpecula	common brush-tailed possum			P	Known	x	x	x	x
Petaurus norfolcensis	squirrel glider			P	Known	x	x	x	x
Petauroides volans	greater glider			P	Known	x	x	x	x
Aepyprymnus rufescens	rufous bettong			P	Likely	x			x
Macropus dorsalis	black-striped wallaby			P	Likely	x		x	x
Dasyurus hallucatus	northern quoll	V		P	Possible			x	
Phascogale tapoatafa	brush-tailed phascogale			P	Possible				
Planigale tenuirostris	narrow-nosed planigale			P	Unlikely				
Petrogale pencillata	brush-tailed rock-wallaby	V			Unlikely				
Pseudomys patrius	eastern pebble-mouse			P	Possible			x	
Zyzomys argurus	common rock rat			P	Possible				
Chalinolobus dwyeri	large-eared pied bat	V			Unlikely				
Chalinolobus nigrogriseus	hoary wattled bat			P	Likely	?			x
Chalinolobus picatus	little pied bat		NT		Likely	x			
Miniopterus australis	little bent-winged bat			P	Unlikely				
Miniopterus schreibersii	large bent-winged bat			P	Likely	x			x
Scotorepens sp. (Parnaby)	central-eastern broad-nosed bat			P	Unlikely				
Vespadelus baverstocki	inland forest bat			P	Likely	?			
Vespadelus regulus	southern forest bat			P	Unlikely				
Pteropus poliocephalus	grey-headed flying-fox	V			Possible				x
Reptiles									
Crocodylus porosus	Salt-water Crocodile	M	V		Unlikely				
Chelodina expansa	Broad-shelled Turtle			P	Known		x	x	x
Emydura albagula	Burnett River Turtle			P	Possible			x	
Rheodytes leukops	Fitzroy River Turtle	V			Possible			x	
Diplodactylus stenodactyus	Gecko			P	Possible				
Strophurus taenicauda taenicauda	Southern golden-tailed gecko		NT		Likely	x		x	x
Delma inornata	Legless Lizard			P	Unlikely				
Delma plebeia	Legless Lizard			P	Unlikely				
Delma torquata	Collared Delma	V	V		Possible				
Paradelma orientalis	Brigalow scaly-foot		V		Likely	x		x	x
Amphibolurus muricatus	Jacky Lizard			P	Possible				

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Scientific Name	Common Name	Threat category			Likelihood of Occurrence (excluding diurnal birds)	Current Survey	Kelly (2011)	^QM	^DEHP (2013b)
		EPBC Act	NC Act	Regional Priority (Brigalow South)					
Chlamydosaurus kingii	Frilled Lizard			P	Possible				x
Intellagama lesueurii lesueurii	Eastern Water Dragon			P	Possible				
Ctenotus ingrami	Skink			P	Unlikely				
Cyclodomorphus gerrardii	Pink-tongued Skink			P	Possible			x	
Egernia rugosa	Yakka Skink	V	V		Possible			x	
Trachdosaurus rugosus	Shingle-back			P	Possible				
Varanus panoptes	Yellow-spotted monitor			P	Likely	x			
Acanthophis antarcticus	Common Death Adder		NT		Possible				
Cryptophis boschmai	Carpentaria Snake			P	Possible				
Denisonia maculata	Ornamental Snake	V	V		Possible				
Furina dunmalli	Dunmall's Snake	V	V		Likely				x
Hemiaspis daemelii	Grey Snake		E		Likely				
Hoplocephalus bitorquatus	Pale-headed Snake			P	Likely			x	
Pseudechis guttatus	Spotted Black Snake			P	Unlikely				
Amphibians									
Limnodynastes salmini	Salmon-striped frog			P	Known	x	x	x	x

EPBC **Environmental Protection and Biodiversity Conservation (National)**
NC **Nature Conservation (Qld)**
V **Vulnerable**
NT **Near Threatened**
M **Migratory**
P **Priority**
X **Known to occur within or near DIWA area**
^ **Recorded within 50km of DIWA boundary**

Appendix B – Site descriptions and faunal habitats

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Site and Faunal Habitat Description	Image
SITE 1 Large, freshwater wetland (ephemeral) in close proximity to Robinson Creek. Scattered *E. populnea* over low grassland on dark, alluvial soils. Area has been cleared and is grazed, but retains a very high percentage grass cover. Soil cracks and tree hollows present. **Co-ords:** WGS84 55J 751296 E / 7177674 N **RE:** 11.3.27 **VMA Class:** least concern **Biodiversity Status:** of concern	
SITE 2 *Acacia harpophylla* woodland with scattered tall Eucalypts and dense low shrubs over low grasses on dark, alluvial soils. Extensive leaf litter cover and moderate grass cover and exfoliating bark. Site has been grazed, though no recent evidence of fire. **Co-ords:** WGS84 55J 754413 E / 7182581 N **RE:** 11.9.5 **VMA Class:** endangered **Biodiversity Status:** endangered	
SITE 3 *Casuarina cristata*/*A. harpophylla* woodland with scattered Eucalypts and low mixed shrubs over grasses on pale, sandy clay loam. Extensive leaf litter and moderate grass cover and stony rises. Dry creek bed within site. This site has experienced grazing, weeds, some clearing and erosion. **Co-ords:** WGS84 55J 777641 E / 7181567 N **RE:** 11.9.5 (partial) **VMA Class:** endangered **Biodiversity Status:** endangered	

Site and Faunal Habitat Description	Image
SITE 4 Drainage channel with dense *Livistona* sp. and tall *Eucalyptus* spp. over mixed grasses and sedges, on dark, alluvial soils. Very high leaf litter and debris cover with ample exfoliating bark and tree hollows. Creek bed and adjacent ephemeral wetland dry. Long unburnt, though grazing and weeds present. **Co-ords:** WGS84 55J 777426 E / 7178325 N **RE:** 11.3.25/11.3.3 **VMA Class:** least concern/of concern **Biodiversity Status:** of concern	
SITE 5. *Eucalyptus crebra* woodland with *Callitris glaucophylla* and mixed shrubs over low grassland on grey sandy clay loam. Grazing and weeds, moderate leaf litter coverage with extensive grass layer. Exfoliating bark and tree hollows present. **Co-ords:** WGS84 55J 782425 E / 7178672 N **RE:** 11.10.7 **VMA Class:** least concern **Biodiversity Status:** no concern	
SITE 6 Rocky hill with *E. creba* and *A. harpophylla* over open shrubs and dense grasses on a brown sandy clay loam. Moderate leaf litter and good log cover with ample exfoliating bark and tree hollows. Some low rocky outcrops and embedded slabs. Some clearing and grazing, particularly on slopes surrounding site. **Co-ords:** WGS84 55J 784335 E / 718412 N **RE:** 11.10.7 **VMA Class:** least concern **Biodiversity Status:** no concern	

Site and Faunal Habitat Description	Image
SITE 7 Riparian woodland on Robinson Creek. Open *Eucalyptus* spp. with scattered tall shrubs over mixed grasses and sedges on a dark clay loam. Almost 100% tall grass coverage, moderate leaf litter and tree hollows present. Waterholes present in the creek, with evidence of grazing, weeds and erosion. **Co-ords:** WGS84 55J 755582 E / 7177248 N **RE:** 11.3.25/11.3.39/11.3.2 **VMA Class:** least concern/of concern **Biodiversity Status:** of concern/no concern	
SITE 8 Tall open *Eucalyptus* spp., *C. glaucophylla* and *C. cristata* over low grassland with sparse sedges on pale clayey-sand. High grass cover with moderate leaf litter cover and some exfoliating bark and good log cover. Scattered rocks and embedded slabs. Evidence of fire, clearing, logging and grazing. **Co-ords:** WGS84 55J 766152 E / 7200344 N **RE:** 11.10.1 **VMA Class:** least concern **Biodiversity Status:** no concern	
SITE 9 Low rocky hill with *Eucalyptus* spp. and *A. harpophylla* over mixed shrubs and low grasses on brown sandy clam loam. Good grass, leaf litter and log cover & exfoliating bark. Some outcropping, scattered rocks and embedded slabs. Small remnant area of *A. harpophylla* woodland. Weeds and grazing evident. **Co-ords:** WGS84 55J 762137 E / 7202565 N **RE:** 11.3.2/11.10.7a/11.3.25 **VMA Class:** of concern/least concern **Biodiversity Status:** of concern/no concern	

Site and Faunal Habitat Description	Image
SITE 10 *Eucalyptus* spp. over mixed shrubs and low mixed grassland on pale clayey sand. High leaf litter and moderate grass cover with tree hollows and exfoliating bark. Evidence of fire, grazing and weeds. **Co-ords:** WGS84 55J 774446 E / 7212606 N **RE:** 11.3.39/11.3.2 **VMA Class:** least concern/of concern **Biodiversity Status:** no concern/of concern	
SITE 11 Riparian woodland on Palm Tree Creek tributary. *Eucalyptus* spp. over tall dense grasses on a dark sandy loam. Almost 100% grass cover with moderate leaf litter. Tree hollows and exfoliating bark present. Creek dry with evidence of grazing, weeds and erosion. **Co-ords:** WGS84 55J 774373 E / 7211795 N **RE:** 11.3.39/11.3.2 **VMA Class:** least concern/of concern **Biodiversity Status:** no concern/of concern	
SITE 12 Large, freshwater wetland (permanent). *Eucalyptus* spp. over mixed grasses and open sedges on grey sandy clay loam. High grass cover with some leaf litter. Exfoliating bark, tree hollows and soil cracks present. Evidence of grazing, weeds and erosion. **Co-ords:** WGS84 55J 772727 E / 7204607 N **RE:** 11.3.27g **VMA Class:** least concern **Biodiversity Status:** of concern	

Appendix C – Terrestrial vertebrate fauna species list (including bats) and methods of detection

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FAMILY and Species	Common Name	Detection Method
Amphibians		
HYLIDAE		
Cyclorana alboguttata	striped burrowing frog	N, F
Cyclorana brevipes	short-footed frog	N, F
Cyclorana novaehollandiae	wide-mouthed frog	N, F
Litoria caerulea	green tree frog	N, F, C, O
Litoria fallax	eastern dwarf sedge frog	N, F, C, O
Litoria latopalmata	broad-palmed frog	N, F, C, O
Litoria peronii	Peron's tree frog	N, F, C, O
Litoria rubella	red tree frog	N, F, C, O
Litoria wilcoxii	eastern stony creek frog	N
LIMNODYNASTIDAE		
Limnodynastes fletcheri	Fletcher's frog	N, F, C, O, Tr
Limnodynastes salmini	salmon-striped frog	N, F, O, Tr
Limnodynastes tasmaniensis	spotted marsh frog	F, O, Tr
Limnodynastes terraereginae	northern banjo frog	F, O, Tr
Platyplectrum ornatum	ornate burrowing frog	N, F, O, Tr
MYOBATRACHIDAE		
Crinia parinsignifera	eastern sign-bearing froglet	^
Reptiles		
CHELUIDAE		
Chelodina expansa	broad-shelled Turtle	^
Chelodina longicollis	snake-necked turtle	O, Tr
Emydura macquarii krefftii	Macquarie turtle	O
AGAMIDAE		
Diporiphora nobbi	common nobbi dragon	O, T
Pogona barbata	eastern beared dragon	O
CARPHODACTYLIDAE		
Underwoodisaurus milii	common thick-tailed gecko	N
COLUBRIDAE		
Boiga irregularis	brown tree snake	N, O
Dendrelaphis punctulata	common tree snake	^
Tropidonophis mairii	keelback	T
DIPLODACTYLIDAE		
Diplodactylus vittatus	eastern stone gecko	N
Nebulifera robusta	robust velvet gecko	N
Amalosia rhombifer	zigzag velvet gecko	N
Strophurus taenicauda taenicauda	southern golden-tailed gecko	N
ELAPIDAE		
Cryptophis nigrescens	eastern small-eyed snake	N, Tr, T
Demansia psammophis psammophis	yellow-faced whip snake	O, Tr, T
Furina diadema	red-naped snake	Tr
Parasuta dwyeri	Dwyer's snake	N
Pseudonaja textilis	eastern brown snake	O, Tr
GEKKONIDAE		
Gehyra dubia	dubious dtella	N, Tr
Heteronotia binoei	Bynoe's gecko	N, Tr, T
PYGOPODIDAE		
Lialis burtonis	Burton's snake-lizard	N
Paradelma orientalis	Brigalow scaly-foot	T
Pygopus schraderi	eastern hooded scaly-foot	Tr
PYTHONIDAE		

FAMILY and Species	Common Name	Detection Method
Antaresia maculosa	spotted python	N
Aspidites melanocephalus	black-headed python	N
Morelia spilota mcdowelli	carpet python	N
SCINCIDAE		
Anomalopus leuckhartii	two-clawed worm-skink	Tr
Anomalopus verreauxii	three-clawed worm-skink	^
Carlia munda	striped rainbow skink	O, Tr, T
Carlia pectoralis	open-litter rainbow skink	O, Tr, T
Carlia schmeltzii	Schmeltz's rainbow skink	Tr
Carlia vivax	lively rainbow skink	O, Tr, T
Cryptoblepharus pulcher pulcher	elegant snake-eyed skink	O, Tr, T
Ctenotus robustus	eastern striped skink	Tr
Lampropholis delicata	delicate skink	†
Lerista fragilis	eastern mulch slider	Tr, T
Lerista punctatovittata	eastern robust slider	Tr, T
Lygisaurus foliorum	tree-base litter-skink	O, Tr, T
Morethia boulengeri	Boulenger's snake-eyed skink	T
Morethia taeniopleura	eastern fire-tailed skink	T
VARANIDAE		
Varanus panoptes panoptes	yellow-spotted monitor	M
Varanus tristis orientalis	freckled monitor	O, Tr
Varanus varius	lace monitor	O
Mammals		
MACROPODIDAE		
Macropus dorsalis	black-striped wallaby	M
Wallabia bicolor	swamp wallaby	N, O, M
Macropus giganteus	eastern grey kangaroo	N, O, M
Macropus parryi	whiptail wallaby	O, M
Macropus robustus	common wallaroo	N, O
Macropus rufiogriseus	red-necked wallaby	N, O
Petrogale herberti	Herbert's rock wallaby	N, T, M
PERAMELIADE		
Isoodon macrourus	northern brown bandicoot	T, M
PETAURIDAE		
Petaurus breviceps	sugar glider	N, CP
Petaurus norfolcensis	squirrel glider	N
PHALANGERIDAE		
Trichosurus vulpecula	common brush-tailed possum	N, O, M
PHASCOLARCTIDAE		
Phascolarctos cinereus	koala	N, T, CP
PSEUDOCHEIRIDAE		
Petauroides volans	greater glider	N, O
POTOROIDAE		
Aepyprymnus rufescens	rufous bettong	N, O, M
PTEROPODIDAE		
Pteropus scapulatus	little red flying-fox	O
TACHYGLOSSIDAE		
Tachyglossus aculeatus	short-beaked echidna	O, M
DASYURIDAE		
Planigale maculata	common planigale	Tr
MURIDAE		
Hydromys chrysogaster	water rat	^

FAMILY and Species	Common Name	Detection Method
Pseudomys delicatulus	delicate mouse	N
Pseudomys gracilicaudatus	eastern chestnut mouse	^
CANIDAE		
Canis lupus dingo	dingo	M
EMBALLONURIDAE		
Saccolaimus flaviventris	yellow-bellied sheath-tailed bat	B
MOLOSSIDAE		
Tadarida australis	white-striped free-tailed bat	B
Chaerephon jobensis	northern free-tailed bat	B
Mormopterus beccarii	Beccari's free-tailed bat	B
Mormopterus species 2	south-eastern free-tailed bat	B
Mormopterus species 3	inland free-tailed bat	B
VESPERTILLIONIDAE		
Chalinolobus gouldii	Gould's wattled bat	B
Chalinolobus morio	chocolate wattled bat	B
Chalinolobus nigrogriseus	hoary wattled bat	*
Chalinolobus picatus	little pied bat	B
Miniopterus schreibersii	large bent-winged bat	B
Nyctophilus sp.	unknown long-eared bat	B
Scotorepens balstoni	inland broad-nosed bat	B
Scotorepens greyii	little broad-nosed bat	B
Vespadelus troughtoni	eastern cave bat	B
Non-native species		
BUFONIDAE		
Rhinella marinus	cane toad	N, F, O, Tr
FELIDAE		
Felis catus	feral cat	N, O, M
LEPORIDAE		
Lepus europaeus	European brown hare	O
Oryctolagus cuniculus	European rabbit	O
SUIDAE		
Sus scrofa	pig	O, M
CANIDAE		
Vulpes vulpes	red fox	N, O
MURIDAE		
Mus musculus	house mouse	Tr
STURNIDAE		
Acridotheres tristis	common myna	O

N **Nocturnal surveys**
F **Frog census**
C **Call detected**
O **Opportunistic**
Tr **Trapped**
T **Targeted searches**
M **Motion Camera**
CP **Call Playback**
B **Bat Detector**
^ **Kelly (2011)**
† **Queensland Museum record**
***** **DEHP (2013)**

Appendix D – Bird species list

FAMILY and Species	Common Name
ACANTHIZIDAE	
Acanthiza apicalis	inland thornbill
Acanthiza nana	yellow thornbill
Acanthiza reguloides	buff-rumped thornbill
Chthonicola sagittata	speckled warbler
Gerygone albogularis	white-throated gerygone
Gerygone fusca	western gerygone
Sericornis frontalis	white-browed scrubwren
Smicrornis brevirostris	weebill
ACCIPITRIDAE	
Accipiter fasciatus	brown goshawk
Aquila audax	wedge-tailed eagle
Haliastur sphenurus	whistling kite
Milvus migrans	black kite
AEGOTHELIDAE	
Aegotheles cristatus	Australian owlet-nightjar
ANATIDAE	
Anas castanea	chestnut Teal
Anas gracilis	grey Teal
Anas rhynchotis	Australasian shoveler
Anas superciliosa	pacific black duck
Aythya australis	hardhead
Chenonetta jubata	Australian wood duck
Cygnus atratus	black Swan
Dendrocygna arcuata	wandering whistling-duck
Nettapus coromandelianus	cotton pygmy-goose
Nettapus pulchellus	green pygmy-goose
ANHINGIDAE	
Anhinga novaehollandiae	Australasian darter
APODIDAE	
Hirundapus caudacutus	white-throated needletail
ARDEIDAE	
Ardea ibis	cattle Egret
Ardea intermedia	intermediate egret
Ardea pacifica	white-necked heron
Egretta novaehollandiae	white-faced heron
Nycticorax caledonicus	nankeen night-heron
ARTAMIDAE	
Artamus leucorynchus	white-breasted woodswallow
Artamus personatus	masked woodswallow
Artamus superciliosus	white-browed woodswallow
Cracticus nigrogularis	pied butcherbird
Cracticus tibicen	Australian magpie
Cracticus torquatus	grey butcherbird
Strepera graculina	pied currawong
CACTUIDAE	
Cacatua galerita	sulphur-crested cockatoo
Eolophus roseicapillus	galah
Nymphicus hollandicus	cockatiel
CAMPEPHAGIDAE	
Coracina maxima	ground cuckoo-shrike
Coracina novaehollandiae	black-faced cuckoo-shrike
Coracina papuensis	white-bellied cuckoo-shrike

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FAMILY and Species	Common Name
Lalage sueurii	white-winged triller
CASUARIIDAE	
Dromaius novaehollandiae	emu
CHARADRIIDAE	
Elseyornis melanops	black-fronted dotterel
Erythrogonys cinctus	red-kneed dotterel
Vanellus miles novaehollandiae	masked lapwing (southern subspecies)
CICONIIDAE	
Ephippiorhynchus asiaticus	black-necked stork
CISTICOLIDAE	
Cisticola exilis	golden-headed cisticola
COLUMBIDAE	
Geopelia cuneata	diamond dove
Geopelia humeralis	bar-shouldered dove
Geopelia striata	peaceful dove
Geophaps scripta scripta	squatter pigeon (southern subspecies)
Ocyphaps lophotes	crested pigeon
Phaps chalcoptera	common bronzewing
CORACIIDAE	
Eurystomus orientalis	dollarbird
CORCORACIDAE	
Corcorax melanorhamphos	white-winged chough
Struthidea cinerea	apostlebird
CORVIDAE	
Corvus coronoides	Australian raven
Corvus orru	torresian crow
CUCULIDAE	
Cacomantis pallidus	pallid cuckoo
Cacomantis variolosus	brush cuckoo
Centropus phasianinus	pheasant coucal
Chalcites lucidus	shining bronze-cuckoo
Eudynamys orientalis	esstern koel
Scythrops novaehollandiae	channel-billed cuckoo
ESTRILDIDAE	
Taeniopygia bichenovii	double-barred finch
Neochmia modesta	plum-headed finch
Taeniopygia guttata	zebra finch
EUROSTOPODIDAE	
Eurostopodus mystacalis	white-throated nightjar
FALCONIDAE	
Falco berigora	brown falcon
Falco cenchroides	Australian kestrel
GLAREOLIODAE	
Stiltia isabella	Australian pratincole
GRUIDAE	
Grus rubicunda	brolga
HALCYONIDAE	
Dacelo leachii	blue-winged kookaburra
Dacelo novaeguineae	laughing kookaburra
Todiramphus macleayii	forest kingfisher
Todiramphus pyrrhopygius	red-backed kingfisher
Todiramphus sanctus	sacred kingfisher
HIRUNDINIDAE	

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FAMILY and Species	Common Name
Petrochelidon nigricans	tree martin
JACANIDAE	
Irediparra gallinacea	comb-crested jacana
LARIDAE	
Chlidonias hybrida	whiskered tern
MALURIDAE	
Malurus lamberti	variegated fairy-wren
Malurus melanocephalus	red-backed fairy-wren
MELIPHAGIDAE	
Entomyzon cyanotis	blue-faced honeyeater
Lichmera indistincta	brown honeyeater
Manorina melanocephala	noisy miner
Melithreptus albogularis	white-throated honeyeater
Melithreptus gularis	black-chinned honeyeater
Melithreptus lunatus	white-naped honeyeater
Nesoptilotis leucotis	white-eared honeyeater
Philemon citreogular	little friarbird
Philemon corniculatus	noisy friarbird
Ptilotula penicillatus	white-plumed honeyeater
MEROPIDAE	
Merops ornatus	rainbow bee-eater
MONARCHIDAE	
Grallina cyanoleuca	magpie-lark
Myiagra inquieta	restless flycatcher
Myiagra rubecula	leaden flycatcher
MOTACILLIDAE	
Anthus novaeseelandiae	Australasian pipit
NECTARINIIDAE	
Dicaeum hirundinaceum	mistletoebird
NEOSITTIDAE	
Daphoenositta chrysoptera	varied sittella
ORIOLIDAE	
Oriolus sagittatus	olive-backed oriole
OTIDIDAE	
Ardeotis australis	Australian bustard
PACHYCEPHALIDAE	
Colluricincla harmonica	grey shrike-thrush
Pachycephala rufiventris	rufous whistler
PARDALOTIDAE	
Pardalotus striatus	striated pardalote
PELECANIDAE	
Pelecanus conspicillatus	Australian pelican
PETROICIDAE	
Eopsaltria australis	eastern yellow robin
Microeca fascinans	jacky winter
PHALACROCORACIDAE	
Microcarbo melanoleucos	little pied cormorant
Phalacrocorax carbo	great cormorant
Phalacrocorax sulcirostris	little black cormorant
Phalacrocorax varius	pied cormorant
PHASIANIDAE	
Coturnix ypsilophora	brown quail
PODARGIDAE	

FAMILY and Species	Common Name
Podargus strigoides	tawny frogmouth
PODICIPEDIDAE	
Podiceps cristatus	great crested grebe
Poliocephalus poliocephalus	hoary-headed grebe
Tachybaptus novaehollandiae	Australasian grebe
POMATOSTOMIDAE	
Pomatostomus temporalis	grey-crowned babbler
PSITTACIDAE	
Alisterus scapularis	Australian king-parrot
Aprosmictus erythropterus	red-winged parrot
Glossopsitta pusilla	little lorikeet
Platycercus adscitus	pale-headed rosella
Psephotus haematonotus	red-rumped parrot
Trichoglossus chlorolepidotus	scaly-breasted lorikeet
Trichoglossus haematodus	moluccanus rainbow lorikeet
RALLIDAE	
Fulica atra	eurasian coot
Gallinula tenebrosa	black-tailed native-hen
RECURVIROSTRIDAE	
Himantopus himantopus	black-winged stilt
Recurvirostra novaehollandiae	red-necked avocet
RHIPIDURIDAE	
Rhipidura albiscapa	grey fantail
Rhipidura leucophrys	willie wagtail
STRIGIDAE	
Ninox connivens	barking owl
Ninox novaeseelandiae	southern boobook
THRESKIORNITHIDAE	
Platalea flavipes	yellow-billed spoonbill
Platalea regia	royal spoonbill
Plegadis falcinellus	glossy ibis
Threskiornis molucca	Australian white ibis
Threskiornis spinicollis	straw-necked ibis
TIMALIIDAE	
Zosterops lateralis	silvereye
TURNICIDAE	
Turnix varia	painted button-quail
TYTONIDAE	
Tyto javanica	eastern barn owl

Appendix E – Bat call identification report

Microbat Call Identification Report

Prepared for ("Client"):	Ray Lloyd
Survey location/project name:	Lake Murphy area (Taroom)
Survey dates:	May & October 2013
Client project reference:	
Job no.:	RL-1301
Report date:	10 December 2013

Methods

Data receipt and processing

Bat call surveys were conducted in May and October 2013 using two Anabat detectors (Titley Scientific, Brisbane) and one Song Meter SM2BAT detector (Wildlife Acoustics, Concord MA, USA.) Survey data were downloaded from the detectors by the client, with Anabat data saved to Anabat call sequence files (zero crossing, or ZC, format) and SM2BAT data saved in the compressed audio format (WAC) as recorded by the detector.

Upon receipt of the data, the SM2BAT WAC files were converted to Anabat sequence files using Wildlife Acoustics' *Kaleidoscope* program. This process yielded 2315 ZC files for the October survey; however, despite several attempts at downloading the May SM2BAT data using a range of filter settings and saving to both ZC and WAV file formats, no bat calls could be generated from the WAC files. Consequently, the remainder of the analysis relied only on October data.

Call identification

The filtered Anabat call sequence files were viewed using *AnalookW* (Corben 2013) and a subset of files containing representative samples of all call types observed for each night on each detector were selected for identification. Species identification was achieved manually by comparing the sonograms of the selected calls with those of with reference calls from southern and central Queensland and with reference to published call descriptions (e.g. Reinhold *et al.* 2001; Pennay *et al*. 2004).

Calls with fewer than four clearly-defined, non-fragmented pulses were excluded from the identification process.

Species' identification was also guided by considering probability of occurrence based on general distribution information (Churchill 2008; van Dyck & Strahan 2008) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online/index.html) and the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Armstrong & Reardon (2006), except *Nyctophilus corbeni* (Parnaby 2009).

Results & Discussion

Data quality and quantity

This was an exceptionally high quality data set, with a very high proportion of sequence files from all detectors containing long-duration clearly-defined bat call passes. Consequently, call identification presented few difficulties and reliability of species attribution was very good for most call types.

Species recorded

At least fourteen and as many as 18 species were recorded during the Lake Murphy October 2013 surveys (see Table 1). Thirteen call types were positively identified to species level and one further call type was positively attributed to the genus *Nyctophilus*. Another two call types could not be reliably identified and could have represented either call variation in species already positively identified or additional species. A number of species likely to occur in the study area share similar call characteristics and can be difficult to reliably identify. These are discussed in more detail below.

Calls/species not reliably identified

Technical terms used in the following descriptions are described in the Glossary.

Chalinolobus gouldii / Mormopterus species 2 / *Mormopterus* species 3

Characteristic frequency (Fc) range overlaps considerably between these species, although pulse shape characteristics and frequency differential were reliably used to identify the majority of calls from this survey. Numerous calls were attributed to *C. gouldii* on the basis of steep FM-qCF pulses with characteristic frequency (Fc) in the range 28-34 kHz and distinctive inter-pulse frequency alternation. Calls with predominantly flat (qCF) pulses at Fc=32-36 kHz were identified to *Mormopterus* sp. 2; while those with flat pulses around 28-30 kHz were attributed to *Mormopterus* sp. 3. A few calls from JT Anabat on 19/10 had FM-qCF pulses with short frequency sweep and variable Fc and could have been from either *C. gouldii* or *M.* species 3.

Chalinolobus nigrogriseus / Scotorepens greyii

These species produce steep FM-qCF pulses with Fc=36-40 kHz and some calls can be difficult to differentiate. Most calls in the frequency range were attributed to *S. greyii* based on relatively short pulse duration and cup-shaped body often with up-swept tail. No calls were positively identified to *C. nigrogriseus*, but a number of calls had longer pulse duration and more angular pulse shapes with flatter body. These characteristics are more typical of *C. nigrogriseus*, but most of calls also included more curved pulses similar to those of *S. greyii*. Both species have been recorded in the Lake Murphy Conservation Park (DEHP 2013).

Chalinolobus picatus / Scotorepens greyii / Vespadelus baverstocki

These species all produce steep FM-qCF call pulses with curved to hooked bodies and Fc overlapping in the range 39-41 kHz. *Scotorepens greyii* was positively identified where calls had uniform Fc at or below 39 kHz (mostly at 37-38 kHz); and numerous calls with distinct alternating Fc were reliably identified to *C. picatus*. *Vespadelus baverstocki* was not reliably identified, but may have been responsible for a number of calls around 41-42 kHz that had variable pulse frequency but no clear evidence of the distinctive alternating pulse frequency attributable to *C. picatus*.

Nyctophilus spp.

Nyctophilus species produce steep, linear calls that are generally distinct from other bats but the species within the genus cannot be reliably differentiated. At least two *Nyctophilus* spp. probably occur in the survey area: *N. bifax* and *N. gouldi*. The Vulnerable *N. corbeni* (EPBC Act and Qld NCA) could also be present in larger tracts of suitable habitat; however, the habitat descriptions and photos provided with the data suggest that the sites where *Nyctophilus* calls were recorded may not provide habitat suitable for *N. corbeni*. The only way of confirming this species' presence would be through a comprehensive trapping survey.

Vespadelus baverstocki / Vespadelus vulturnus / Miniopterus schreibersii

Vespadelus baverstocki (Fc=40-46 kHz) and *V. vulturnus* (Fc=44-50 kHz) calls overlap in frequency and have almost identical pulse shapes (steep, broad frequency sweep FM-qCF of short-duration, usually with hooked body). The *Vespadelus* spp. frequency overlap zone (44-46 kHz) is also occupied by *M. schreibersii*, although most calls from that species have shorter frequency sweep FM-qCF pulses of longer duration, with more angular shape and flat or diagonal body. The majority of calls in the frequency range were of the latter type, representing *M. schreibersii*; however several calls at 45-46 kHz had intermediate pulse characteristics and could have been from either of the *Vespadelus* spp.

References

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van Dyck, S. and Strahan, R. (ed.) (2008). *The Mammals of Australia* (Third Edition). New Holland; Sydney.

Table 1. Microbat species recorded during the Lake Murphy surveys, October 2013.

♦ = species positively identified from call data

□ = species possibly present, but not reliably identified

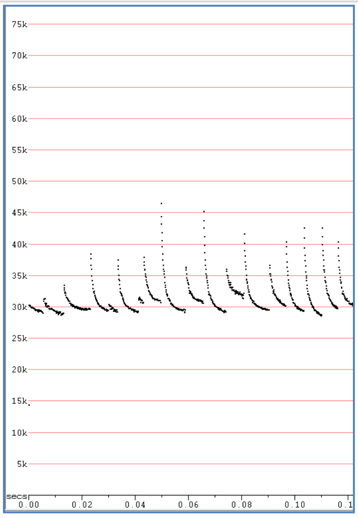
Detector:	**JT ANABAT**				**RL ANABAT**					**RL-SM2**					
Date:	19-Oct	22-Oct	23-Oct	25-Oct	17-Oct	18-Oct	19-Oct	21-Oct	23-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct
Survey ID:	Bat4	Bat6	Bat7	Bat9	Bat1	Bat2	Bat3	Bat5	Bat8	SM1	SM2	SM3	SM4	SM5	SM6
Total sequence files:	107	22	323	87	587	136	99	83	218	18	122	848	584	705	38
No. calls identified:	34	5	43	18	70	24	19	39	28	12	46	102	72	58	24
Chalinolobus gouldii	♦		♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Chalinolobus morio					♦										
Chalinolobus nigrogriseus								□				□	□	□	
Chalinolobus picatus	♦	♦	♦	♦	♦	□	♦	♦	□	♦	♦	♦	♦	□	♦
Nyctophilus species	♦		♦		♦			♦	♦	♦	♦	♦	♦		♦
Scotorepens balstoni			♦		♦	♦			♦		♦	♦		♦	
Scotorepens greyii	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Vespadelus baverstocki					□	□					□	□			□
Vespadelus troughtoni							♦						♦	♦	♦
Vespadelus vulturnus					□							□			
Miniopterus schreibersii	♦		♦		♦			♦			♦	♦	♦		♦
Tadarida australis	♦	♦	♦				♦	♦							
Chaerephon jobensis	♦	♦		♦			♦		♦	♦	♦	♦			
Mormopterus beccarii	♦		♦		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Mormopterus species 2			♦		♦	♦		♦	♦		♦	♦	♦	♦	♦
Mormopterus species 3	□				♦	♦			♦		♦	♦	♦	♦	
Saccolaimus flaviventris	♦		♦	♦		♦	♦	♦				♦	♦	♦	♦

Glossary

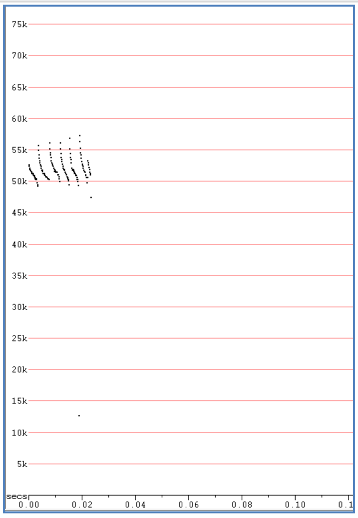
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

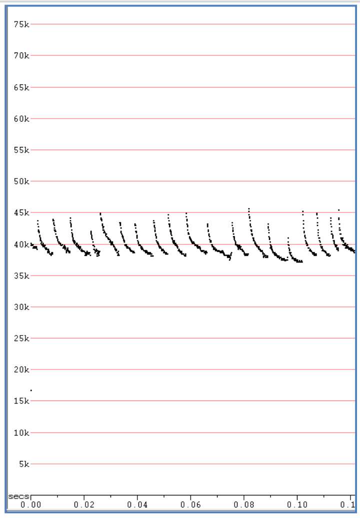
Appendix 1 Representative call sequences from the Lake Murphy survey, October 2013.
(Scale: 10msec per tick; time between pulses removed)



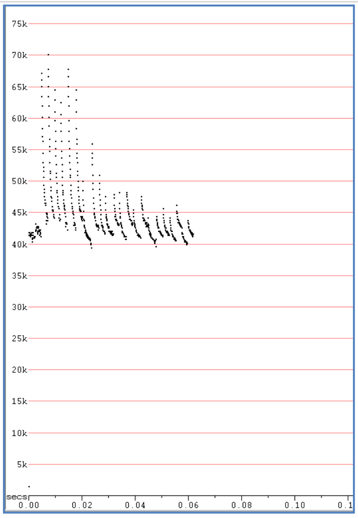
Chalinolobus gouldii



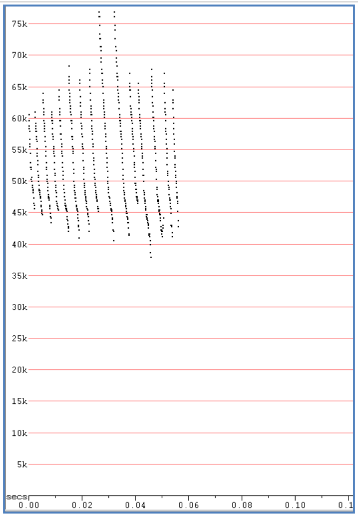
Chalinolobus morio



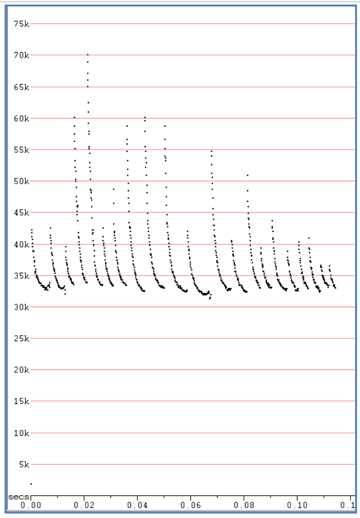
Probably *Chalinolobus nigrogriseus*



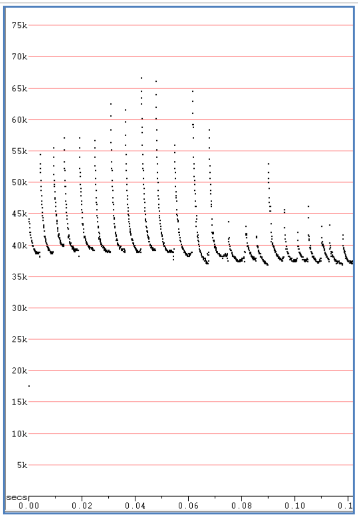
Chalinolobus picatus



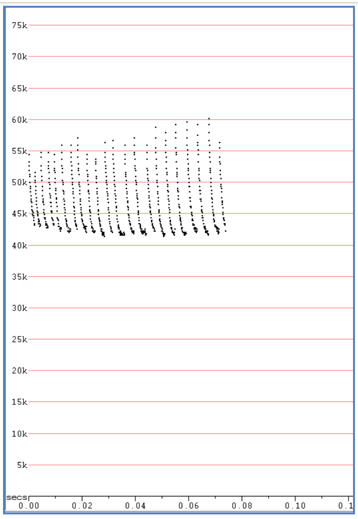
Nyctophilus sp.



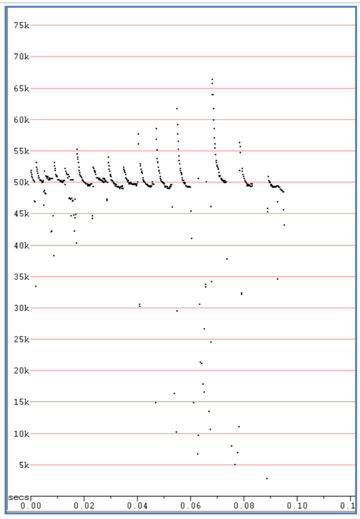
Scotorepens balstoni



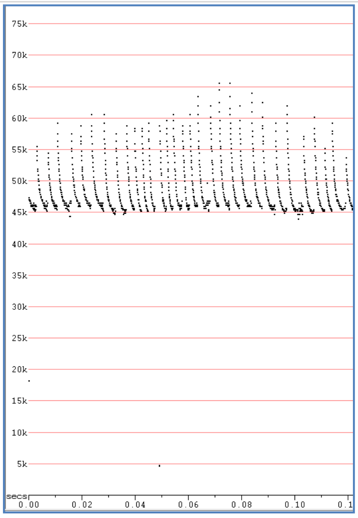
Scotorepens greyii



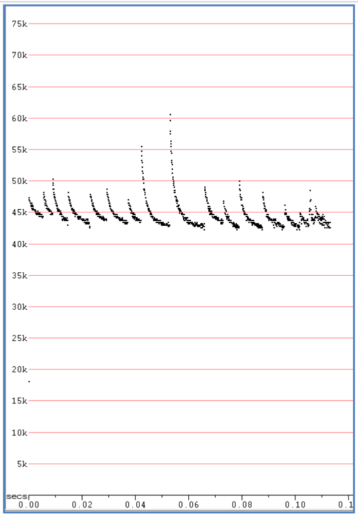
Probably *Vespadelus baverstocki*



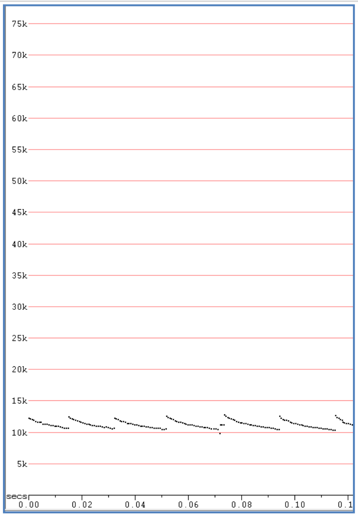
Vespadelus troughtoni



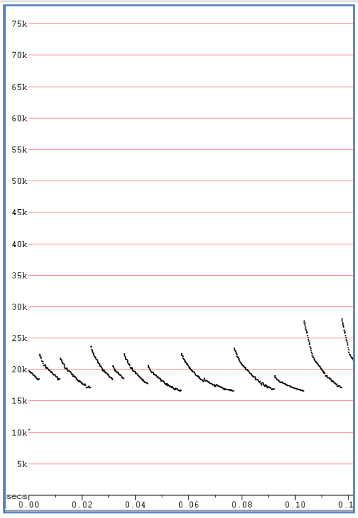
Probably *Vespadelus vulturnus*



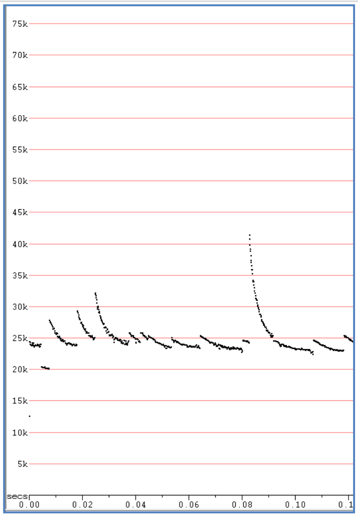
Miniopterus schreibersii



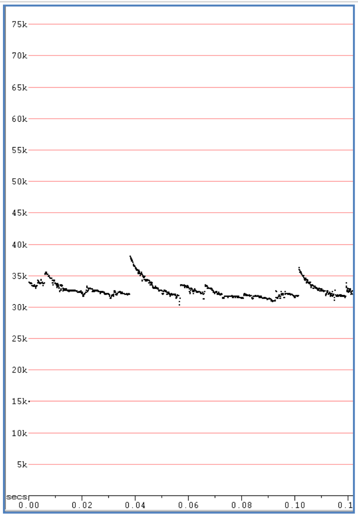
Tadarida australis



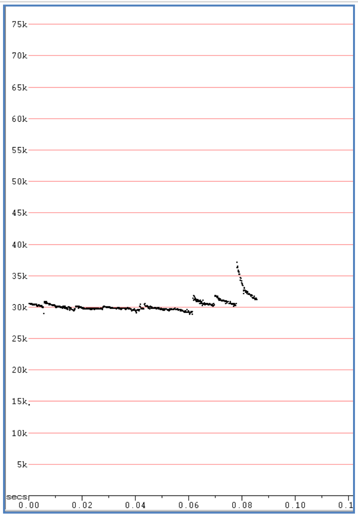
Chaerephon jobensis



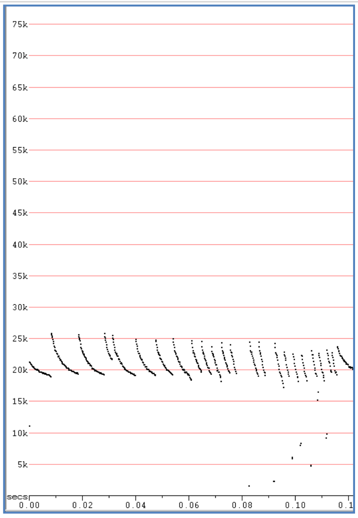
Mormopterus beccarii



Mormopterus species 2



Mormopterus species 3



Saccolaimus flaviventris

Our country, Our future.

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FITZROY BASIN ASSOCIATION

Flora Report

Flora Report – Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by J.J. Halford & R. J. Fensham for Fitzroy Basin Association Inc.

Flora Report – Palm Tree & Robinson Creek Wetlands

The development of this report was supported by the Fitzroy Basin Association Incorporated (FBA) through funding from the Australian Government and Santos GLNG.

This report was prepared on behalf of FBA by the Department of Biological Sciences, University of Queensland.

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Summary

Australia has an extensive network of inland wetland systems. Wetlands are important to ecological health at the landscape level as they filter nutrients, suspended sediment and assist in rainwater retention. Inland wetlands are ecologically important resources to local flora and fauna as well as migratory species. The Australian Government has recognised the importance of wetlands by becoming a signatory to the Ramsar convention and through the establishment of a Directory of Important Wetlands. Yet despite this recognition little is known of inland wetland system flora and the environmental variables that determine species distribution. Understanding these processes helps to inform land managers how to best manage and conserve these valuable ecosystems.

The Palm Tree and Robinson Creek wetlands are a spectacular example of inland ephemeral wetlands and are recognised on the Directory of Important Wetlands in Australia. These wetlands support a highly diverse flora and fauna including local and migratory species. A flora survey was conducted as part of a greater initiative to help better understand the value of these wetlands, as well as to identify threatening processes affecting wetland health. A total of 190 vascular plant species were recorded in the flora survey. An analysis of the survey identified eight vegetation groups within the Palm Tree and Robinson Creek wetlands, consisting of deep and shallow water aquatics and terrestrial shore zones. The distribution of these zones was determined mostly by water depth, salinity and slope gradients.

As many wetland species are broadly distributed, no species surveyed in the wetland zones are considered to be significant in terms of threats or rarity. The significance of these wetlands is more likely to lie in their importance to local and migratory fauna species. Ecologically the Palm Tree and Robinson Creek wetlands appear to be in reasonably good health. This is mostly due to appropriate stocking rates and a lack of water regulation. The greatest current threats to these wetlands are the invasive species Lippia (*Phyla canescens*) and feral animals such as pigs (*Sus scrofa*) and cats (*Felis catis*). However significant threats lie in the presence of the invasive species cat's claw vine (*Macfadyena unguis-cati*) in the riparian zone of Palm Tree Creek and introduced ponded pasture species downstream in the Dawson River catchment. Recommendations on monitoring and treatment of the current threats are discussed. Future threats to these wetlands may include the long-term effects of climate change on wet and dry cycles, as well as potential water impoundments, resource extraction or other developments that affect the hydrology within the wetlands.

Acknowledgements

The authors wish to thank the Fitzroy Basin Association for establishing this project and administering the funding for the research. Many thanks also to the landholders within the study area who provided access to their wetlands; and Adam Clark and other past and present landholders for providing an historical context to the function of the wetlands. The authors further wish to thank Queensland Herbarium staff who provided considerable logistical and field support (Jeremy Drimer, Chris Pennay, Mark Edgington) as well as botanical advice (Gordon Guymer, Tony Bean, Ron Booth, John Thompson) and also Will Smith for assistance with Figures 1 and 3.

Glossary and Acronyms

ASL	Above Sea Level
DIWA	Directory of Important Wetlands in Australia
FBA	Fitzroy Basin Association Inc.
Lacustrine	A lake wetland
Palustrine	A swamp wetland
Ramsar Convention	An intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources

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1 Introduction

1.1 Background

Wetlands can be defined as areas of temporary or permanent inundation that at times support organisms that, for some part of their life cycle, are adapted to and depend upon wet conditions for their survival (Department of Environment and Resource Management 2011). Despite relatively dry continental climatic conditions, Australia has a surprisingly extensive wetland system, including a considerable presence within the arid and semi-arid interior (see Paijmans et al. 1985). The seasonal and intermittent wetlands of Australia's interior contain the greatest species diversity in native wetland vegetation (Paijmans et al. 1985). Due to the temporary nature of arid and semi-arid wetlands, species have developed strategies to survive periods of long-term drought and inundation (Beadle 1981; Brock 1994). Temporary wetlands are heavily relied upon as habitat, not only by the species that occupy them on a full-time basis, but also by wide ranging terrestrial species that rely on them as a water and food resource. Wetlands are also important to ecological health as they filter nutrients and suspended sediment and assist in rainwater retention (Blanch and Brock 1994). As a signatory to the Ramsar Convention, the Australian Government recognises the ecological importance of wetlands and has further developed a Directory of Important Wetlands (see Environment Australia 2001).

Yet despite the recognised ecological importance of Australian wetland ecosystems, they have been poorly studied in comparison with other ecological communities (Boon and Brock 1994). One of the best ways to understand wetland ecosystems is to try to understand the ecological processes that occur within them. This might include investigations such as flora and fauna surveys that identify species requiring conservation protection, studies into wetland health and investigations into threatening processes such as the effects of invasive weeds and feral animals. Understanding these processes then equips land managers with further knowledge on how best to sustainably manage these ecosystems into the future.

In recognition of the ecological and agricultural importance of inland wetlands, the Fitzroy Basin Association has established a research project to investigate the ecological significance of the ephemeral wetlands of the Palm Tree and Robinson Creek catchments of the upper Dawson River catchment in central Queensland. These wetlands are a complex series of lakes, lagoons and swamps that are a valuable ecological and agricultural resource within the region and are listed on the Federal Government's Directory of Important Wetlands (see Environment Australia 2001). This broad survey encompassed hydrology and water quality studies, flora and fauna surveys and a documentation of the history of these wetlands. A component of this investigation and the subject of this current report was a wetland flora survey. The aim of this survey was to identify and classify the vegetation groups present and to determine the environmental factors that influence the species composition of each vegetation group. Furthermore, the purpose of this survey was to identify environmentally significant plant communities and flora species that have specific conservation requirements.

This report provides a description of the vegetation groups identified from the survey and highlights the environmental factors driving each. A brief comparison is made between the vegetation recorded during this survey and the Queensland Government Regional Ecosystem mapping for these wetlands. The presence or absence of environmentally significant flora species are mentioned along with any conservation requirements. Potential ecological threats faced by these wetlands were also investigated and recommendations are given to manage these threats. Understanding these ecological processes within the Palm Tree and Robinson Creek wetland systems will increase the understanding of vegetation patterns in temporary inland Australian wetlands more broadly and assist in future management decisions that will ultimately lead to better ecological outcomes for these complex systems.

2 Methods

2.1 Study Site

The study site was located in the Palm Tree and Robinson Creek catchments. These catchments are sub-catchments of the Dawson River with the confluence of the two systems located approximately 19km north of the township of Taroom (approx. S25.49° E149.76°) at approximately 200m asl, in the semi-arid Brigalow Belt bioregion. Taroom has an annual mean maximum temperature of 28.2° and an annual mean minimum temperature of 13.6°. The average annual rainfall at Taroom is 674mm with 47.5 days of totals ≥ 1mm, mostly falling from October to March (Bureau of Meteorology 2013). The wetlands are represented by approximately 153 ephemeral lakes and reedy swamps (following methods outlined in Alluvium (2014) and with the exception of Lake Murphy (lacustrine), all wetlands are mapped by the Queensland Government as palustrine (Department of Environment and Heritage Protection 2012). Palustrine wetlands are defined as non-channelled, vegetated (>30% emergent) wetlands of less than eight hectares, whilst lacustrine wetlands are large (>8ha), open and dominated by water (Department of Environment and Resource Management 2011). These wetlands are positioned adjacent to the Palm Tree, Robinson and other major creeks within their catchments (see Figure 1). They are perched at elevations higher than the adjacent creeks and thus require sufficient flood events that breech creek embankments to fill. The wetlands are formed at the outlets of small gullies and drainage lines by the formation of natural berms and levies that impede flow to the more substantial creeks located adjacent. However despite their location within these minor subcatchments, rarely do these wetlands fill from their local subcatchment alone. Rather, they require a major contribution of floodwaters backfilling from flooded major creeks located nearby (A. Clark pers. comm.). Lake Murphy is currently the only wetland in this complex contained within the Queensland reserve system (Lake Murphy Conservation Park).

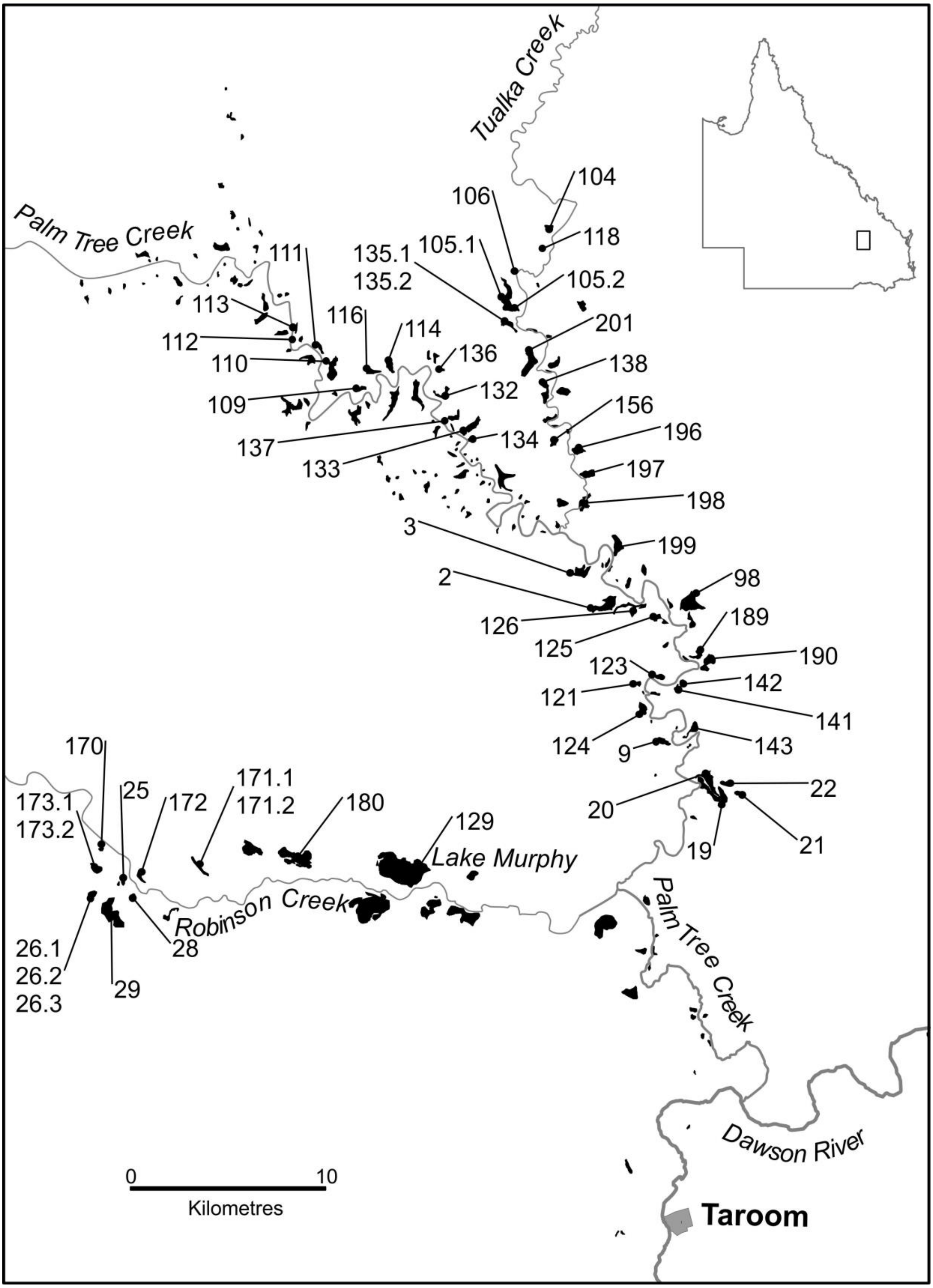

Figure 1: Map of the Palm tree and Robinson Creek wetlands with numbers representing only those wetlands surveyed. These numbers correspond to the unique numbers allocated to each wetland during the

initial desk top assessment of appropriate wetlands for survey. Wetlands in which multiple transects were carried out are represented by decimal numbers.

2.2 Sampling design and fieldwork

A desk top assessment of all appropriate wetlands was carried out using Queensland Government wetland*info* 100K map tiles (Department of Environment and Heritage Protection 2012). Each wetland identified from within the study site was allocated a unique number. The survey was carried out on 52 accessible wetlands on 15 properties (see Figure 2) during March, April and July of 2013. As the vegetation zones were often distinct and regularly banded around the entire shoreline, each wetland was surveyed at one survey location at each wetland. Exceptions to this occurred where the vegetation was considerably different around the shore, in which case more than one survey location was established. A total of 58 survey locations were investigated from the 52 wetlands and each location was surveyed during one visit only.

Wetlands were surveyed from the edge of the tree line to the deepest identifiable zone. The edge of the tree line was identified as the fixed, uppermost mark of the shoreline, below which inundation is too frequent and/or prolonged to support woody vegetation. Thus, the tree line creates a static level in the landscape from which to measure a wetland from its holding capacity, regardless of the water level present at the time of survey. For wetlands that were cleared of fringing woody vegetation, this 'tree line' datum was positioned at the point where cosmopolitan shoreline vegetation (such as wetland dependant herbs) was replaced by terrestrial ground layer species (such as pasture species) dominant within the surrounding landscape. This change in ground layer vegetation was consistent with the transition occurring in the ground layer under the tree line in those wetlands where a fringing tree line persisted.

A tape was projected from the tree line to the deepest aquatic zone, perpendicular to and dissecting each of the identified vegetation zones present. For the purpose of the flora survey, this projected tape was used as a centreline to project two plots in opposite directions at the centre of each vegetation zone present. Beginning at two meters either side of the centreline, each plot measured 15 meters in length × 2 meters wide (30 m^2 each). The two plots were counted separately and all vascular plant species recorded in the first 1 m length of each 15 m long plot (2 m^2) received an abundance score of four. Species not recorded in the first 2 m^2, but occurring in the following 2 m length (4 m^2) received an abundance score of three. Previously unrecorded species recorded in the next 4 m length (8 m^2) received an abundance score of two, whilst those species only present in the final 8 m length (16 m^2) received an abundance score of one. Scores for each species recorded in a vegetation zone from the two plots either side of the centreline were later combined so that all species had an abundance value between zero and eight. Species that were present in the vicinity but not within the plots were given an abundance score of 0.5. This process was completed for each of the vegetation zones determined for each survey location. Voucher specimens were collected for identification purposes and were lodged at the Queensland Herbarium if fertile material was available for collection. Species were identified using the nomenclature of Bostock and Holland

(2010), however the exotic status of a given species was determined as the likely absence of that species from the Australian continent at the time of permanent European settlement in 1788.

The environmental gradients measured in this survey were depth below tree line, bank slope, soil conductivity, soil pH and soil texture. Depth below tree line and bank slope were measured with a surveyor's dumpy level and staff. Bank slope was calculated from the fall of each vegetation zone divided by the zone width, measured along the projected tapeline. The deepest zones were given a slope of zero. Five surface soil samples were collected from each vegetation zone and these subsamples were mixed before a final single sample was obtained. Soil texture was determined by the manipulation of dampened soil into ribbons. The length of each ribbon determined texture in relation to clay content (<25mm = <20% clay, 25-40mm = 20-30% clay, 40-50mm = 30-35% clay, 50-75mm = 35-40% clay, >75mm = >40% clay). Soil pH and soil conductivity was measured in the laboratory using a TPS pH meter and probe to a dilution of 2.5 grams of soil in 70ml of distilled water. Disturbance from feral pigs and cattle were noted at each wetland, as was the presence of the invasive weeds lippia and introduced ponded pasture species. Where observed, previous man-made alterations to wetland hydrology were also recorded.

Figure 2: Flora survey methodology: determining vegetation zones (top left) Image: J. Drimer; recording the slope of vegetation zones with dumpy level and staff (top right) Image: J. Halford, and (bottom left) Image: J. Drimer; laying out the transect line in a vegetation zone for recording species presence and abundance (bottom right) Image J. Halford.

2.3 Statistical Analysis

A three-dimensional ordination space was developed for the floristic data using non-metric multi-dimensional scaling. The relative strength of the environmental vectors was evaluated using the Monte-Carlo correlation coefficient and the default settings in DECODA (Minchin 1991). The floristic plots were compared using the Bray Curtis similarity test incorporating species abundance values and a dendrogram was prepared using the Resemblance (1) matrix procedure with the Primer 6 software (Clarke and Gorley 2006). Groups were determined by exploring for environmental differences and after examining ANOSIM outputs that highlight similarities in species composition between each group. Differences in environmental variables between the final floristic groups were determined using Kruskal-Wallis one-way analysis of variance, a relatively conservative test that can be conducted on skewed data.

The flora was assigned to three categories reflecting their dependence on inundation: 1) wetland dependant species: those species that require or can tolerate extended periods of inundation; 2) wetland shore species: those species that cannot tolerate extended periods of inundation but are more often confined to wetlands; and 3) terrestrial species: those species that are more common in broader terrestrial habitats. A subcategory of the wetland dependant species was also developed to represent species dependent on the water column for survival. Assigning species to these categories was informed by observations from this survey or the expert opinion of other botanists, as well as an examination of the habitat notes in the Queensland Herbarium records (Queensland Herbarium 2013).

3 Results

3.1 Vegetation

A total of 190 plant species were recorded from 191 vegetation zones from the 58 location points surveyed at 52 wetlands. Of the 190 species recorded, 35 were classified as wetland dependant. Thirteen of these 35 wetland dependant species were considered to be dependent upon the water column for survival. Of the remaining 155 species, a further 66 of these were considered to be wetland shore species intolerant of inundation but observed more commonly on the shore than above the tree line, whilst another 89 species were considered to be dryland terrestrial species more commonly found in the broader landscape. Of the 190 species recorded, 43 were considered to be introduced species, 30 of which fell into the terrestrial species category. None of the species recorded are currently listed as Endangered, Vulnerable or Near Threatened species under either the Queensland Government *Nature Conservation Act 1992* or the Australian Government *Environment Protection and Biodiversity Conservation Act 1999*.

Of the 73 species contributing an abundance >10% in any vegetation group, 21 were wetland dependant, 33 were considered wetland shore species, 19 were considered to be terrestrial species more commonly found in the broader landscape, whilst 16 were considered to be introduced. Species richness and abundance were highest in Group 4 and lowest in Group 1. The species with the greatest abundance scores were *Ludwigia peploides* subsp. *montevidensis*, followed by *Pseudorhaphis spinescens*.

Table 1: The percentage frequency of plant species according to the eight floristic groups. Only species with a frequency great than 10% in any one group are included. Wetland dependent species are also identified as well as the habitat preference of each species. Exotic species are identified with an asterisk.

Species name	water column dependant	habitat preference	1	2	3	4	5	6	7	8
Aeschynomene indica	no	wetland shore				51	2	12	6	1
Alternanthera denticulata	no	wetland shore			2	83	1	10	9	
*Aster subulatus**	no	wetland shore				39		2	3	1
Azolla pinnata	yes	wetland dependant					3	1	5	11
Carex appressa	no	wetland shore				9	4	5	8	
Centella asiatica	no	wetland shore				34			3	
Centipeda minima	no	wetland shore				25	2	1	3	2
Chrysopogon filipes	no	wetland shore				9		3	11	
*Cirsium vulgare**	no	terrestrial				26			1	
Convolvulus graminetinus	no	wetland shore				35				
*Conyza sumatrensis**	no	terrestrial				50			4	
Cullen tenax	no	wetland shore				20		2		
*Cynodon dactylon **	no	wetland shore				82		7	18	

Species name	water column dependant	habitat preference	1	2	3	4	5	6	7	8
Cyperus bifax	no	wetland shore				3	1		7	
Cyperus difformis	no	wetland shore				24	1	16	12	4
Cyperus exaltatus	no	wetland dependent				60	3	4	9	10
Cyperus victoriensis	no	wetland shore				2		1	12	
Dentella repens	no	wetland shore				35			2	
Dichondra repens	no	wetland shore				19				
Dysphania pumilio	no	wetland shore				20		1		
Echinochloa colona *	no	wetland shore			2	55		19	5	4
Echinochloa inundata	no	wetland dependent				13	2	3	2	4
Eleocharis plana	no	wetland dependent		1		4	2	4	34	16
Eleocharis sphacelata	yes	wetland dependent		3		5	26	12	11	4
Eragrostis elongata	no	terrestrial				21			2	
Eragrostis parviflora	no	wetland shore				85	1		6	1
Eriochloa procera	no	wetland shore				9	1		2	
Eucalyptus tereticornis subsp. *tereticornis*	no	terrestrial				62	1	1	6	3
Euphorbia dallachyana	no	terrestrial				14			1	1
Evolvulus alsinoides var. *villosicalyx*	no	terrestrial				11				
Fimbristylis dichotoma	no	wetland shore				14				
*Glandularia aristigera**	no	terrestrial				27				
Glinus lotoides	no	wetland shore			2	90		2	4	2
Glinus oppositifolius	no	wetland shore				49			1	
Glycine tomentella	no	terrestrial				14				
*Gomphrena celosioides**	no	terrestrial				10				
*Heliotropium indicum**	no	wetland shore				28	2		4	
Hibiscus verdcourtii	no	wetland shore				33		3		
Hypericum gramineum	no	wetland shore				23				
Juncus usitatus	no	wetland dependent		1		47	3	3	20	2
Ludwigia peploides subsp. *montevidensis*	no	wetland dependent		1	2	103	9	30	35	41
Malvastrum americanum var. *stellatum*	no	terrestrial				31			1	
*Malvastrum coromandelianum**	no	terrestrial				17				
Marsilea drummondii	no	wetland dependent				7		1	31	
Marsilea mutica	yes	wetland dependent		8		7	4	12	21	50
Najas tenuifolia	yes	wetland dependent		12				2		18
Nymphaea gigantea	yes	wetland dependent		40			8		1	14
Nymphoides crenata	yes	wetland dependent				1	2	3	15	23
Nymphoides indica	yes	wetland dependent		1					2	10
Ottelia ovalifolia	yes	wetland dependent		4			4	3	3	15
Oxalis perennans	no	terrestrial				16				
Paspalidium distans	no	wetland shore				11		1	4	
Paspalum distichum	no	wetland dependent				35	5	26	17	2

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Species name	water column dependant	habitat preference	1	2	3	4	5	6	7	8
Persicaria lapathifolia	no	wetland dependent				29	2	8	2	7
Persicaria orientalis	no	wetland dependent				19	4	6	5	5
Persicaria prostrata	no	wetland dependent				76	1	8	11	3
*Phyla canescens**	no	wetland shore				21			7	
Polygonum plebeium	no	wetland shore			1	62	1		2	2
Polymeria pusilla	no	wetland shore				11				
Pseudoraphis spinescens	no	wetland dependent		8		44	17	7	31	48
Pterocaulon redolens	no	terrestrial				11				
Senna barclayana	no	terrestrial				31				
Sesbania cannabina	no	wetland shore			4	23	1	7		1
Sida hackettiana	no	terrestrial				56				
*Sida rhombifolia**	no	terrestrial				73		5	5	
*Solanum nodiflorum**	no	terrestrial				16		1	1	
*Soliva anthemifolia**	no	wetland shore				11	1		6	
*Sonchus oleraceus**	no	terrestrial				11				
Spirodela oligorhiza	yes	wetland dependent		1			6	7	1	13
Swainsona luteola	no	wetland shore				70		1	1	
Vallisneria nana	yes	wetland dependent		39		1				13
*Verbena incompta**	no	terrestrial				30				
*Xanthium occidentale**	no	wetland shore				17	2	3	14	

Eight vegetation groups were recognised from the cluster analysis: Group One, Bare ground; Group Two, *Vallisneria nana*/ *Nymphaea gigantea* herbfield; Group Three, *Sesbania cannabina* herbfield; Group Four, *Ludwigia peploides*/ *Glinus lotoides* herbfield; Group Five, *Eleocharis sphacelata* sedgeland; Group Six, *Paspalum distichum*/ *Ludwigia peploides* grassland; Group Seven, *Eleocharis plana*/ *Ludwigia peploides* sedgeland; and Group Eight, *Pseudoraphis spinescens*/ *Marsilea mutica* grassland. The vegetation groups identified in the analysis were significantly different from each other. The dissimilarity percentages between all groups ranged from 76.18% to 100%, as demonstrated in the dendrogram (Figure 3). The most similar groups were Groups Seven and Eight at 76.18% dissimilarity.

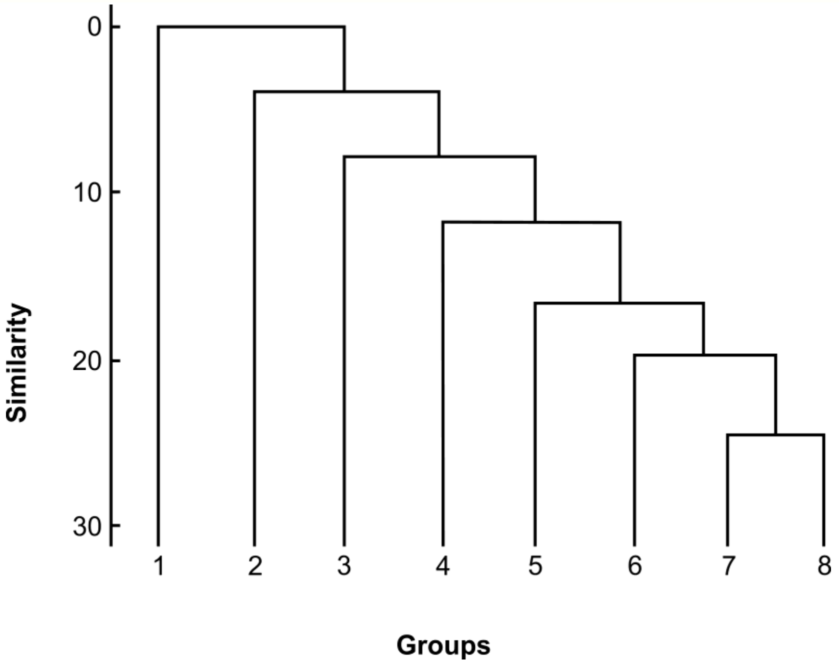

Figure 3: A dendrogram illustrating the eight vegetation groups identified using the Bray-Curtis similarity test. Dissimilarity percentages ranged from 76.18% to 100%. Group One: Bare ground; Group Two: *Vallisneria nana/ Nymphaea gigantea* herbfield; Group Three: *Sesbania cannabina* herbfield; Group Four: *Ludwigia peploides/ Glinus lotoides* herbfield; Group Five: *Eleocharis sphacelata* sedgeland; Group Six: *Paspalum distichum/ Ludwigia peploides* grassland; Group Seven: *Eleocharis plana/ Ludwigia peploides* sedgeland; Group Eight: *Pseudoraphis spinescens/ Marsilea mutica* grassland.

3.2 Environmental Gradients

The vector analysis revealed that water depth was by the far the most important environmental factor influencing the vegetation groups (R = 0.482), followed by conductivity (0.288), slope (0.217), soil texture (0.198) and pH (0.126). The greatest depth below tree line recorded for any deep aquatic zone was 2.09m. Bank steepness values of the zones measured (height (m)/length (m)) ranged from 0.002m to 1.03m. Soil pH values ranged from 5.28 to 7.42, soil conductivity ranged from 6.68 to 146.4µS/cm, whist ribbon length ranged from 28mm to 103mm.

Table 2: Significant differences in the relationships between vegetation groups and environmental factors

Variable (Group)	1	2	3	4	5	6	7	8
Depth below tree line (m)	0.765 (0.653-1.356)AC	1.0675 (0.7145-1.589)A	0.88 (0.868-0.892)	0.365 (0.144-1.086)D	0.567 (0.187-0.884)CD	0.46 (0.078-0.608)BD	0.145 (0.05-0.53)B	0.565 (0.335-1.058)C
Slope (h m/l m)	0 (0-0)A	0 (0-0)A	0 (0-0)	0.043 (0.011-0.086)B	0 (0-0.032)A	0.024 (0.001-0.037)C	0.035 (0.021-0.09)B	0.026 (0-0.055)C
Soil pH	6.12 (5.972-6.358)AC	6.07 (5.558-6.628)AC	6.355 (6.271-6.439)	6.085 (5.646-6.693)A	5.715 (5.523-6.172)BD	5.9 (5.488-6.32)ACD	5.71 (5.54-6.07)BD	5.82 (5.48-6.257)CD
Soil conductivity (µS/cm)	45.7 (32.92-114.52)A	21.495 (13.268-32.39)C	49.55 (46.71-52.39)	18.58 (9.219-45.5)BC	19.465 (11.947-38.96)BD	37.3 (9.87-62.76)ACD	19.62 (12.73-29.8)BC	16.64 (10.223-25.46)B
Soil texture (ribbon length (mm))	72 (70.4-73)AB	75 (61.9-83.1)B	67.5 (64.7-70.3)	65 (44.9-76)A	75.5 (65.5-78.7)BC	71 (62.6-77)BC	71 (53-78)AC	72 (61.4-87.6)AB
Number of sites	5	30	2	70	14	17	21	32

As is evident in Table 2, the zones with only occasional vascular plant species present, the bare ground zones of (Group One) had high soil conductivity compared to all other groups except the *Paspalum distichum*/ *Ludwigia peploides* grassland zones (Group Six), from which it had lower slopes and greater depth below tree line. The *Vallisneria nana*/ *Nymphaea gigantea* herbfield zones (Group Two) had greater depth than all other zones except the bare ground zones (Group One). A *Sesbania cannabina* herbfield zone (Group Three) was only rarely sampled and was not included in the statistical analysis of the environment. It was a very species poor tall annual herbfield that sporadically occurs on dry wetland beds. The *Ludwigia peploides/ Glinus lotoides* herbfield zones (Group Four) had shallower depth below the tree line than all other zones with the exception of the *Eleocharis sphacelata* sedgeland zones (Group Five) and the *Paspalum distichum*/ *Ludwigia peploides* grassland zones (Group Six) from which Group Four had steeper slope. The *Eleocharis sphacelata* sedgeland zones (Group Five) had low soil pH and/or shallower slope compared to other zones. The *Paspalum distichum*/ *Ludwigia peploides* grassland zones (Group Six) were relatively flat compared to other zones except the *Pseudorhaphis spinescens/ Marsilea mutica* grassland zones (Group Eight), from which it was shallower and had higher soil conductivity. The *Eleocharis plana* sedgeland zones (Group Seven) was different in depth to all other zones except the *Paspalum distichum*/ *Ludwigia peploides* grassland zones (Group Six), which occur on lesser slopes. The *Pseudorhaphis spinescens/ Marsilea mutica* grassland zones (Group Eight) was different in depth to all other zones, with the exception of the zone without plant species (Group One) and the *Eleocharis sphacelata* sedgeland zones (Group Five), which had gentler slopes.

3.3 Invasive Species

Lippia was present in 24 of the 52 wetlands surveyed. Of these, lippia was present below the tree line in 15 wetlands, in vegetation zones represented by Group Four (*Ludwigia peploides/ Glinus lotoides* herbfield) and Group Seven (*Eleocharis plana* sedgeland). No introduced ponded pasture species were found in the wetlands surveyed in the Palm Tree and Robinson Creek catchments, or from opportunistic searches that were carried out in surrounding creeks and gully lines. Other declared weeds such as parthenium were also absent from the survey, however the riparian zone of Palm Tree Creek was infested with the invasive species *Macfadyena unguis-cati* (cat's claw vine) and notes were made on its extent and degree of infestation, for use in future weed control programs.

4 Discussion

4.1 Vegetation

4.1.1 Vegetation Overview

The wetland and adjacent surrounding vegetation essentially corresponds with Regional Ecosystem mapping. The vegetation adjacent to the wetlands varied in type and extent depending on topography and geology. Although sometimes cleared, fringing vegetation was most often *Eucalyptus tereticornis* and/or *Eucalyptus coolabah* (forest red gum and/or coolibah) woodland or retained paddock trees and clumps that suggest this. This vegetation was more extensive on the broader floodplain of the Robinson Creek catchment, which also contained woodland species such as *Eucalyptus populneus* (poplar box), *E. melanophloia* (silver-leaved ironbark), *Corymbia tessellaris* (Moreton Bay ash) and *Angophora floribunda* (rough-barked apple) on sandier levies and embankments. Low surrounding hills in the Robinson Creek catchment supported mostly cleared and regrowth *Acacia harpophylla* (brigalow) and/or *E. populneus* (poplar box) woodland. Due to the more hilly topography of the Palm Tree Creek catchment, fringing vegetation of *Eucalyptus tereticornis* (forest red gum), *E. coolabah* (coolibah) and *Lophostemon suaveolens* (swamp box) often quickly gave way to species such as *Eucalyptus populneus* (poplar box) or *E. melanophloia* (silver-leaved ironbark), *Corymbia tessellaris* (Moreton Bay ash) and *Callitrus glaucophylla* (white cypress), particularly in the upper catchment.

The majority of species recorded during this survey are considered to be reasonably common and widespread, especially the cosmopolitan annuals, such as *Glinus lotoides* (lotus sweetjuice) that colonise recently exposed shorelines. Of the 35 wetland dependant species present, most also occur naturally outside Australia, with the likely vector for the dispersal of aquatic plant species being migratory birds (Thorne 1972; Beadle 1981; Kloot 1984; Brock 1994; Jacobs and Wilson 1996). Based on an investigation into species distribution of the recorded aquatic flora using collection data generated from Australia's Virtual Herbarium, a slight bias occurs towards a more tropical aquatic flora. There were no aquatic species recorded during the survey that are not distributed throughout the Australian tropics, although the sedge *Eleocharis pusilla* (small spike rush) becomes uncommon in the tropics. Furthermore, six species are considered predominately tropical with an extension into subtropical areas: *Leersia hexandra* (native rice grass), *Ludwigia octovalvis* (willow primrose), *Monochoria cyanea* (monochoria), *Nymphaea gigantea* (giant water lily), *Schoenoplectus lateriflorus* (a sedge), *Utricularia stellaris* (a bladderwort).

Of the 190 species recorded in the wetland survey, none currently occur on the *Environment Protection and Biodiversity Conservation Act 1999* and *Nature Conservation Act 1992* threatened species lists. There were however, some species that are considered uncommon or poorly known and are poorly represented in the Queensland Herbarium collection (e.g. the terrestrial perennial *Abutilon subviscosum* (an abutilon)). Although the local fan palm *Livistona nitida* (Carnarvon fan palm) is listed under the *Nature Conservation Act 1992* as Near Threatened, this species is more commonly found in the broader floodplain areas of these catchments and as such data for this species were not captured during the wetland survey. Incidental collections were also made of significant species within the surrounding floodplain during this survey. These include the collection from a solitary specimen of *Melaleuca phratra* (a pink-flowered Bottlebrush) from Sandstone Creek in the upper Robinson Creek catchment, and a collection from a population of *Glycyrrhiza acanthocarpa* (native liquorice) from Waunui Lake. *Melaleuca phratra* is a recently described bottlebrush from southern Queensland that has a widespread though very patchy distribution of small populations. A listing of Vulnerable has been suggested for this species, however a greater understanding of overall numbers and threats must be determined before such a listing can occur (Craven 2009). The small shrub *Glycyrrhiza acanthocarpa* or native liquorice is a member of the pea family. The species is considered "Least Concern", however it is a more common in wetlands within southern parts of the Murray-Darling Basin and southern Western Australia. It is very uncommon in the northern extent of its range. Indeed, the only other record of this species in the Queensland Herbarium collection from the Leichhardt pastoral district is from Bogantungan west of Emerald, collected in 1909 (Queensland Herbarium 2013). A collection was also made of the near threatened perennial subshrub pea *Desmodium macrocarpum* (large-podded trefoil) from the adjacent sandstone hills in the upper Palm Tree catchment.

Remnants of several plant communities surrounding wetlands are federally listed as Threatened Ecological Communities and are protected under the *Environment Protection and Biodiversity Conservation Act 1999*. These include Brigalow (*Acacia harpophylla* dominant and co-dominant) and Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions (see Department of Environment 2009). Of environmental significance within the floodplain network of the Palm Tree and Robinson Creeks are the coolibah (*Eucalyptus coolabah*) floodplains. These intermittent floodplain wetlands fall outside the scope of the current study but are significantly important components of floodplain ecology and are likely to contribute to the overall ecological health of these wetland ecosystems.

4.1.2 Vegetation classification and environment relations

Studies based on the vegetation-environment relations of Australian wetlands are limited in number. However such studies help us to understand why certain plants occur where they do. For example, the few investigations into vegetation-environment relations of inland Australian wetlands have identified water regime and salinity as the most significant environmental gradients effecting wetland species distribution (e.g. Brock 1981; Brock and Lane 1983; Kirkpatrick and Harwood 1983; Smith et al. 2009). These environmental factors can also determine the number of species present within a particular habitat. Often in particular habitats such as wetlands, the number of species present decreases as environmental factors such as salinity and water depth become more extreme. In these more extreme conditions only species with specialised adaptations can persist (Paijmans et al. 1985; Brock 1994).

From this current survey, the vegetation groups identified in the analysis can be distinguished by one another not only in terms of their species compositions but by their relationships to the environmental factors present within the wetlands. The vegetation groups were most strongly influenced by their depth below tree line, soil conductivity and slope. With the exception of the importance of slope, these findings are similar to other works conducted on vegetation-environmental relations in inland Australian wetlands (salinity (Smith et al. 2009) and a combination of salinity and water regime (see Brock 1981; Brock and Lane 1983; Kirkpatrick and Harwood 1983)). Researchers working on the soil seed banks of inland wetlands also refer to water regime as the main influence on species composition (see Casanova and Brock 2000; Nicol et al. 2003; James et al. 2007), whilst studies conducted on particular species of wetland flora also highlight the influence water regime has on the life history and reproductive adaptation of inland wetland species (e.g. Brock 1991; Blanch and Brock 1994; Froend and McComb 1994; Rea and Ganf 1994).

Water depth is the dominant environmental factor determining species composition in the wetlands of the Palm Tree and Robinson Creeks. Depth is linked to water regime as those wetland zones with the greatest depth below the tree line will be more frequently inundated for longer periods compared to those zones at a shallower depth to the tree line. The ability of some wetland vegetation to establish may also occur as a result of variable drainage, hence the importance of slope in the current findings. Whilst steeper zones are more likely to drain following the recession of water levels and following intermittent rainfall events, wetland zones with gentler slopes are more likely to pond water following these events. As such, the duration of inundation is not only a consequence of topographic depth but also slope.

Whilst some other studies have demonstrated the great importance of salinity as a determinant of species composition within wetlands (e.g. Brock and Lane 1983; Smith et al. 2009), the current study only showed salinity as having a moderate influence on species composition. However these previous studies were carried out in wetlands where salinity occurred in much higher ranges and at much higher levels, whereas the soils present within the current study area are only of low to moderate salinity (see McNeil and Raymond 2013). It has been suggested that salinity has limited effects on species distribution except in conditions where salinity is high (Beadle 1981).

Of the eight vegetation groups identified, those with the greatest depth to tree line (i.e. those most frequently inundated) had the lowest species richness and abundance. These groups include Groups One, Two and to a lesser extent Group Five. The species that compose these particular groups are specialist wetland species that have adapted to extended periods of inundation. Mid to shallow aquatic zones such as Groups Five, Six, Seven and Eight can be dominated by emergents such as *Eleocharis* (rush) species or floating and submerged species such as *Marsilea* species (nardoos), *Ludwigia peploides* (water primrose) and *Psuedoraphis spinescens* (floating couch grass). When inundated, these medium to shallow depth groups often contain ornamental native aquatics species such as *Ottelia ovalifolia* (swamp lily), *Monochoria cyanea* (monochoria), *Potamogeton tricarinatus* (floating pondweed), *Nymphoides crenata* (wavy marshwort) and *Nymphoides indica* (snowflake marshwort).

Figure 4: An example of some of the ornamental species found in the shallow marginal to moderately deep aquatics - left: *Nymphoides indica* (snowflake marshwort); centre: *Monochoria cyanea* (monochoria); right: *Nymphoides crenata* (wavy marshwort). Images: C. Pennay.

The different vegetation groups are described as follows.

Group One: Bare ground, was an uncommon deep water aquatic group almost totally devoid of vegetation. Group One zones were surveyed at five sites from four wetlands (three wetlands in the upper Robinson Creek catchment and one in the Palm Tree Creek catchment). It is doubtful that this group permanently lacks or maintains limited vegetation and is possibly at an early stage in the greater cycle of vegetation establishment following inundation. However, without the insight into wetland permanence and associated vegetation cycles afforded by multiple site visits, a proper assessment of vegetative abundance of this group is too difficult to provide. Despite this, the Group One wetland present in the Palm Tree Creek also lacked vegetation during a preliminary visit to the site during October 2012, six months prior to the wetland being surveyed. Group One zones are characterised by high soil conductivity, substantial depth below the tree line, and a relatively flat slope.

Figure 5: Group One – bare ground. A Shallow to deep aquatic with limited to no vegetation present, Belle Eau Lake. Image: J. Halford

Group Two: *Vallisneria nana*/ *Nymphaea gigantea* herbfield consisted of deep water zones dominated by the submerged aquatic *Vallisneria nana* (ribbon weed) and the floating attached aquatic *Nymphaea gigantea* (giant water lily). These deep water zones of submerged and attached floating vegetation correspond with descriptions of deep water wetland vegetation structure presented in earlier literature (see Beadle 1981; Paijmans et al. 1985; Brock 1994) with the presence of the tropical *Nymphaea gigantea* within the subtropics. An obvious absence from this group is *Nelumbo nucifera* (pink lotus) which has been recorded in wetlands downstream in the Dawson catchment further north, as well as the Condamine catchment of the Murray-Darling Basin to the south. Submerged aquatic species of Group Two, such as *Vallisneria nana* and *Najas tenuifolia* (Australian naiad), are important food sources for some wetland bird species. Black swans (*Cignus atratus*) were observed grazing on these species during the survey. Group Two is characterised by substantial depth below the tree line.

Figure 6: Group Two - *Vallisneria nana*/ *Nymphaea gigantea* herbfield, Bloomfield Lake, Bloomfield. Image: J. Halford.

Group Three: *Sesbania cannabina* tall herbfield was recorded at two sites within the one wetland. This wetland was unique in that it was the only dry wetland surveyed consisting of a dense, *Sesbania cannabina* (sesbania pea) dominated, tall herbfield. This group was low in species richness. This is likely to be attributable to the deep shade generated by the density of the dominant species, stifling species present in the ground layer. Although eliminated from gradient analysis due to lack of replicates, this wetland appears to resemble Group One by its relatively high soil conductivity.

Figure 7: Group Three – *Sesbania cannabina* tall herbfield on a dry-bedded wetland (Group Four in foreground) at Broadmere property. Image J. Halford.

Group Four: *Ludwigia peploides*/ *Glinus lotoides* herbfield consisted of zones dominated by terrestrial annual species. These annuals are mostly opportunistic species that are able to colonise bare, damp ground quickly and complete there life cycles in a relatively short period of time. They are considerably fecund species that are able to produce a large quantity of seed within a season. Group Four is often dominated by the common and widespread species *Ludwigia peploides* (water primrose) and *Glinus lotoides* (lotus sweetjuice). However the species compositions present within Group Four zones are highly variable and although generally dominant, these two species were not always surveyed in Group Four zones. This vegetation group also consists of a majority of species more commonly found in dryland plant communities (*n*=89), of which a large quantity are exotic. Many of these dryland species are annual and short-lived perennial species with similar life history traits to those species more commonly found in wetland shore vegetation. Of the exotics present in Group Four, one species *Phyla canescens* (lippia) is considered invasive. Group Four is characterised by a shallow depth to the tree line with banks steep in slope and soils with comparatively low clay content.

Figure 8: Group Four – *Ludwigia peploides*/ *Glinus lotoides* herbfield consisting of zones dominated by terrestrial annual species. Three vegetation zones of Group Four are present here on the shore of a wetland on the Robinson Creek property, the central zone dominated by *Glinus lotoides* (Lotus Sweetjuice). Image J. Drimer.

Group Five: *Eleocharis sphacelata* sedgeland consisted of swamp vegetation dominated by *Eleocharis sphacelata* (tall spike rush) with *Pseudoraphis spinescens* (floating couch grass) and *Nymphaea gigantea* (giant water lily) sometimes subdominant. *Pseudoraphis spinescens* is a common feature of tropical floodplain swamps (Beadle 1981; Paijmans et al. 1985). The combined presence of *Eleocharis sphacelata* and *Nymphaea gigantea* can be explained by swamp depth. Within swamps that are deeper, the usually dominant emergent species (such as *Eleocharis sphacelata*) are likely to occur in concert with attached floating species (such as *Nymphaea gigantea*) that are usually more common in floodplain lakes (Paijmans et al. 1985). *Eleocharis sphacelata* is an important species for nesting waterbirds (Briggs 1979; Tulloch et al. 1988; Bayliss and Yeomans 1990). *Eleocharis sphacelata* can dominate the invasive species lippia if managed correctly (Price et al. 2010). Group Five is characterised by moderate depth, low soil pH, and banks of substantially flat slope.

Figure 9: Group Five - *Eleocharis sphacelata* sedgeland dominating this swamp at La Palma. Image: J. Halford.

Figure 10: The structure of Group Five, formed by the dominant emergent *Eleocharis sphacelatus* (tall spike Rush) makes for ideal nesting sites for waterbirds, particularly when open water is also available, as is the case here on a wetland at Box Tree property. Image: J. Halford.

Group Six: *Paspalum distichum*/ *Ludwigia peploides* grassland was dominated by the shallow aquatic *Paspalum distichum* (water couch) and *Ludwigia peploides* (water primrose) with occasional sub-dominance by the introduced grass *Echinochloa colona* (awnless barnyard grass), as well as *Cyperus* *difformis* (dirty dora). *Paspalum distichum* can outcompete lippia (Mawhinney 2003) but is susceptible to lippia invasion if overgrazed (Price et al. 2010). Group Six is characterised by a very shallow depth to the tree line, a bank of moderately steep slope and moderate conductivity.

Figure 11: Group 6 – *Paspalum distichum*/ *Ludwigia peploides* grassland at a shallow wetland at Broadmere property. Image: J. Halford.

Group Seven: *Eleocharis plana*/ *Ludwigia peploides* sedgeland was dominated by the sedge *Eleocharis plana* (ribbed spike rush) and *Ludwigia peploides* (water primrose) with *Pseudoraphis spinescens* (floating couch grass) and *Marsilea drummondii* (common nardoo) subdominant. *Eleocharis plana* creates a dense emergent structure characteristic of shallow aquatic zones (Paijmans et al. 1985; Brock 1994). Other abundant species of this group are common components of these shallower habitats (see Beadle 1981; Paijmans et al. 1985). Two important species of this group (*Ludwigia peploides* and *Pseudoraphis spinescens*) were the most abundant species recorded during the survey. Lippia was also recorded in this vegetation group. *Eleocharis plana* has the ability to outcompete lippia under favourable conditions (MacDonald et al. 2012). *Eleocharis plana* was also a dominant component of swamp vegetation utilised as a nesting site for the vulnerable Australian painted snipe (*Rostratula benghalensis*) in the channel country of south western Queensland (Jaensch 2003), a species also observed breeding on the central Queensland coast (Jaensch et al. 2004). Group Seven is characterised by very shallow depth to the tree line, banks with a very steep slope and low soil pH.

Figure 12: Group Seven – *Eleocharis plana*/ *Ludwigia peploides* sedgeland in the shallows of a wetland at the No.4 property. Image: J. Halford.

Group Eight: *Pseudorhaphis spinescens*/ *Marsilea mutica* grassland consisted of shallow to marginal aquatic zones dominated by *Pseudoraphis spinescens* (floating couch grass) and *Marsilea mutica* (nardoo) with *Ludwigia peploides* (water primrose) subdominant. This group also supports attached floating species such as *Nymphoides crenata* (wavy marshwort), *Ottelia ovalifolia* (swamp lily) and the submerged species *Najas tenuifolia* (Australian naiad). Many of these species are common and widespread (Beadle 1981; Paijmans et al. 1985). Similar to Group Seven, was the strong presence in Group Eight of the commonly occurring species *Ludwigia peploides* and *Pseudoraphis spinescens*. Group 8 is characterised by moderate depth and banks with a moderate slope and low pH.

Figure 13: Group 8 – *Pseudorhaphis spinescens*/ *Marsilea mutica* grassland, dominated here by *Marsilea mutica* on a wetland at La Palma. Image: C. Pennay.

Figure 14: Group 8 – *Pseudorhaphis spinescens*/ *Marsilea mutica* grassland, dominated here by Pseudorhaphis spinescens, on a separate wetland at La Palma. Image: C. Pennay.

4.2 Threatening Processes

The species composition of wetland vegetation can be affected by a variety of threatening processes. Wetlands of inland areas such as those in the Murray-Darling Basin are highly susceptible to invasion by the introduced plant lippia, (*Phyla canescens*), whereas those wetlands present in sub-coastal subtropical and tropical environments are threatened by the introduced ponded pasture species olive hymenachne (*Hymenachne amplexicaulis*), para grass (*Brachiaria mutica*), and aleman grass (*Echinochloa polystachya*). All of these species have the ability to outcompete native species across extensive areas of wetland (Arthington et al. 1983; Rea and Storrs 1999; Houston and Duivenvoorden 2002; Wearne et al. 2010; Price et al. 2011). The spread of these invasive species over extensive wetland areas is often aided by the broad connectivity of many wetlands throughout the landscape (Rea and Storrs 1999).

Introduced predators such as feral cats (*Felis catus*) and the red fox (*Vulpes vulpes*) have had a devastating effect on the biodiversity of arid and semi-arid Australia. These introduced predators are considered to be one of the main causes of native animal extinction within Australia (Kinnear et al. 2010; Saunders et al. 2010). This is especially so for medium sized mammals of arid and semi-arid areas (McKenzie et al. 2007; Johnson and Isaac 2009), but smaller species of birds and reptiles are also susceptible (Read and Bowen 2001; Read and Cunningham 2010). Feral pigs (*Sus scrofa*) can also have a detrimental effect on native wildlife. Feral pigs destroy and displace plants in the shrub and herb layer and consume native animals (Crome and Moore 1990; Fordham et al. 2006). They also spread disease (Pavlov et al. 1992), and create disturbance that allow for the invasion of weed species (Fensham et al. 1994).

Furthermore, poor land management practices such as excessive grazing and the alteration of water regimes can also be detrimental to wetland vegetation and overall wetland health (for example see Wahren et al. 1999). Excessive grazing can cause a shift in species composition where dominant palatable species, such as perennial herbs, are replaced by annual species, including exotics that are adaptable to increases in disturbance regimes (e.g. Lunt et al. 2007a; Lunt et al. 2007b). Excessive grazing can also cause a significant reduction in the biomass produced by native plants and can lead to an increase in exotic weed species (Blanch and Brock 1994; Lunt et al. 2007b, Robertson and Rowling 2000). Trampling caused by the concentration of stock at watering points can lead to soil compaction and increased erosion (James et al. 1999; Jansen and Robertson 2001; Tongway et al. 2003). Erosive processes associated with land clearing and overgrazing can cause an increase in siltation in wetlands that in turn reduces water depth and water quality and can ultimately cause changes in species composition (Lavery and Blackman 1971). Changes to water regimes (the artificial withholding or altering the amount and timing of flow) in wetlands can also alter species composition and cause long-term detrimental effects to wetland health (Brock et al. 1999), including the promotion of invasive species (Whalley et al. 2011).

4.2.1 Feral Animals

The presence of both feral cats and feral pigs was evident at a number of wetlands. Evidence of feral cat predation on native avifauna including wetland birds was found at several wetlands. This was particularly evident at wetlands in which the shoreline vegetation consisted of dense stands of tufted herbs such as *Juncus usitatus* (common rush), at close proximity to the water's edge where resting shore birds can be ambushed over short distance.

Figure 15: Predation of waterbirds by feral predators such as cats made easy by the protection of dense vegetation on the lake shore. Image: J. Halford.

Feral pigs have been documented as being responsible for egg predation of ground nesting birds and reptiles, spreading disease and weeds throughout the landscape as well as causing general disturbance and destruction of ground layer vegetation. The presence of feral pigs was recorded from almost all wetlands with evidence ranging from tracks and scats to wallows and rooting. Of particular note was the extensive damage caused by rooting to Group Four vegetation zones dominated by the sedge *Fimbristylis dichotoma* (common fringe-rush) at several wetlands in the upper Palm Tree Creek catchment and subcatchments. Presumably the bulbs at the base of these sedges were a favoured food of pigs during the period in which these wetlands were surveyed.

Figure 16: Feral pigs are a nuisance pest that spread disease, predate eggs of ground nesting birds and reptiles and destroy ground layer vegetation. Mob at the water's edge Waunui Lake. Image: J. Drimer.

4.2.2 Invasive Weeds

A total of 44 introduced plant species were recorded during the flora survey, however none of these species are currently present on the Queensland Government list of declared plants (Department of Agriculture, Fisheries and Forestry 2013). The majority of these species are naturalised, cosmopolitan annual or short-lived perennial species that opportunistically colonise bare ground areas (such as wetland shores) in the same fashion as native species with similar life history traits. These introduced species are considered naturalised but pose no great ecological threat to the wetlands. Indeed, most are more commonly found in the broader agricultural landscape and are unlikely to persist during inundation, but recolonise after the water recedes. One introduced species however, *Phyla canescens* (Lippia), has the potential to become a serious threat to the Palm Tree and Robinson Creek wetlands.

Lippia is a prostrate perennial of South American origin. The species is present in all Australian states and territories except for the Northern Territory, preferring clay soils in temperate and subtropical climates that are semi-arid or wetter (Julien et al. 2004; Stokes et al. 2008). The species forms dense mats with creeping stems rooting at the nodes, is drought resistant and once established expansion can be rapid. Lippia develops deep tap roots and extensive mats of fibrous roots. It exacerbates erosion by contributing to deep soil drying that leads to bank slumping, particularly in riparian areas consisting of cracking clay soils (Julien et al. 2004). Lippia generates a large seed bank in Australia (Price et al. 2011; MacDonald et al. 2012) and reproduction is via germination of seed and vegetative material with dispersal generated by floodwaters (Julien et al. 2004; MacDonald et al. 2012). Lippia infestations show limited response to herbicide treatment, and the species is seldom grazed by livestock. As such, heavy infestations reduce grazing capacity and can cause complete destocking in extreme cases (Julien et al. 2004; MacDonald et al. 2012). Lippia has become established as a major environmental weed of the Murray-Darling Basin. In 2003, lippia was thought to infest more than 5.3 million hectares within the Murray-Darling Basin at a cost to the grazing industry of $38 million p.a. and an environmental cost of $1.8 billion p.a. (Julien et al. 2004). Recruitment appears to be only possible following flood events (MacDonald et al. 2012). Whereas some authors have demonstrated greater recruitment from seed (e.g. Price et al. 2010), others have suggested colonisation is facilitated more effectively via vegetative material (Price et al. 2011). Lippia increases in numbers following all flood events but is more successful at recruitment survival following winter or frequent floods of shorter duration (Julien et al. 2004; Stokes et al. 2008; Price et al. 2010; Price et al. 2011; Whalley et al. 2011). Alternatively, flood events that inundate lippia for greater than three months reduce the species density due to seedling mortality. Furthermore, flood height also plays a role in determining lippia density as deep floods force populations into sub-optimal habitats on higher ground (Stokes et al. 2008).

Figure 17: Lippia – *Phyla canescens* – is a serious environmental and pastoral weed of the Murray-Darling wetlands. Its distribution and effects in the Palm Tree and Robinson Creek wetlands needs to be monitored. Photo: J. Halford.

Whilst lippia has become a major agricultural and environmental weed of the Murray-Darling Basin (see Julien 2004), it has as yet shown no sign of becoming a similar problem in the Fitzroy Basin. Within the wetlands of the Palm Tree and Robinson Creek wetlands, the presence of lippia was limited to 24 of 52 wetlands surveyed and on observation, lippia was patchy on ground and showed no sign of becoming dominant within the herb layer. Of those wetlands where lippia occurred, it was present below the tree line in 15 wetlands, however most of these occurrences were at higher elevations on the shore. This distribution demonstrates either a preference for elevations that receive intermittent or shallow inundation, or an aversion to prolonged inundation.

The failure of lippia to invade the Dawson River catchment as extensively as some catchments of the Murray-Darling Basin is perplexing. Lippia was first recorded in the Dawson River catchment at Kianga in 1965, whereas the first recording in the neighbouring Condamine catchment of the Murray-Darling Basin was at Warra in 1951 (Queensland Herbarium 2013). The Condamine catchment is heavily infested with lippia (Julien et al. 2004). Although the current study area is approaching the northern limit of current extent for lippia in Queensland, climatically the catchment is well within the parameters of temperature threshold for germination and seedling establishment (see MacDonald et al. 2012).

It is possible that lippia is often more prevalent in the Palm Tree Creek and Robinson Creek wetlands than what our results show. The inundation caused by a significant flood event in 2011, as well as minor follow-up flooding in 2013, has likely reduced the presence of lippia to suboptimal higher elevations (see Stokes et al. 2008). Price et al. (2010) noted an increase in recruits following winter flooding but a decrease in recruits and survivorship following summer flooding with lippia confined to higher ground. Price et al. (2010) also observed an increase in native species cover following summer floods. Even so, discussions with landholders suggest that, anecdotally at least, lippia is yet to cause negative impacts agriculturally or ecologically to these wetlands.

Changes to water regime (the retention of summer rainfall coupled with regular regulated winter releases) has been identified as potentially one of the main contributors to the success of lippia in the worst effected catchments of the Murray-Darling Basin (Mawhinney 2003; Whalley et al. 2011). Whilst lippia increases in numbers following all flood events, it is more successful at recruitment survival following winter floods or frequent floods of shorter duration (Julien et al. 2004; Stokes et al. 2008; Price et al. 2010; Price et al. 2011; Whalley et al. 2011). The Palm Tree Creek and Robinson Creek catchments however, lack the manipulated, frequent winter flooding regimes of these affected Murray-Darling systems and are more often flooded during summer-autumn rain events. We suggest that the absence of regulated flows and a cycle of flooding with a summer-autumn bias limit the capacity for lippia to dominate in the Dawson River catchment and its subcatchments, including the Palm Tree and Robinson Creeks.

Despite the apparent restricted ability of lippia to heavily infest the Dawson River catchment, this species requires on-going monitoring for increases in coverage and outbreaks of new infestations. Maintaining sustainable stocking rates is advisable so as not to adversely impact native species likely to outcompete lippia. Lippia seedlings are easily outcompeted by other plants in grazing exclosures (MacDonald et al. 2012). Whalley et al. (2011) suggest reduced grazing pressure brought about by low stocking rates and rotational grazing may limit the ability of lippia to dominate the ground layer. Furthermore, Price et al. (2010) noted a lack of lippia expansion following winter floods, where existing native groundcover was higher due to a spell from grazing. Further investigations into why lippia has not been as successful in invading the Fitzroy Basin might provide important answers that assist in the control of the species within the Murray-Darling Basin.

Another invasive plant species of considerable concern within the Palm Tree Creek catchment is *Macfadyena unguis-cati* (cat's claw vine). Cat's claw vine is a perennial woody climber native to South America. Cat's claw vine is a serious environmental weed of coastal Queensland and New South Wales (Downey and Turnbull 2007) and poses a significant threat to rainforest and riparian remnants (Batianoff and Butler 2003). Cat's claw is listed federally as a "Weed of National Significance" and is a Class 3 Declared Plant in Queensland. Batianoff and Butler (2002) ranked cat's claw as the fourth most invasive weed in south-east Queensland. Cat's claw vine has the ability to climb most surfaces vertically with the aid of tendrils terminating in three hooks. The plant roots at the node, which in climbing stems become adventitious anchors as they penetrate the outer bark of host plants (Downey and Turnbull 2007). The species is reasonably shade tolerant, which combined with vigorous growth and tightly twining stems, enables plants to shade out the crown and stifle the growth of host trees. This stifling eventually results in limb loss under the weight of the vine (Downey and Turnbull 2007). Dense infestations result in the death of the host and ultimately canopy collapse. Without support, the vine covers the ground in dense mats, smothering native plants in the ground layer and restricting recruitment and regeneration (Downey and Turnbull 2007). The species produces showy, yellow, trumpet-shaped flowers for which it was originally promoted as an ornamental. Fruits are long flattened capsules that produce many seeds with fine, membranous, papery wings that enable the seed to be dispersed via wind or water. The ability for cat's claw vine to be spread in this manner enables rapid establishment along water courses. This quick establishment, coupled with the vigorous growth that reduces structure and destroys native species, results in the rapid degradation of riparian communities. Furthermore, cat's claw produces an extensive network of roots and subterranean tubers that render treatment of the species difficult and time consuming.

This species was observed along the Palm Tree Creek with patchy though dense infestations from at least the adjacent upstream of the Palm Tree Creek crossing of the Fitzroy Development Road to at least the immediate downstream of the Palm Tree Creek at the Ghinghinda Road crossing. It is possible the original source of this infestation is in the upper Palm Tree catchment at the old Ruined Castle homestead (Adam Clark pers comm.), though this requires on-ground confirmation. Whilst not observed in vegetation surrounding wetlands, the potential for cat's claw vine to spread into the vegetation surrounding the wetlands remains a real concern and one that may require serious investigation into long-term control.

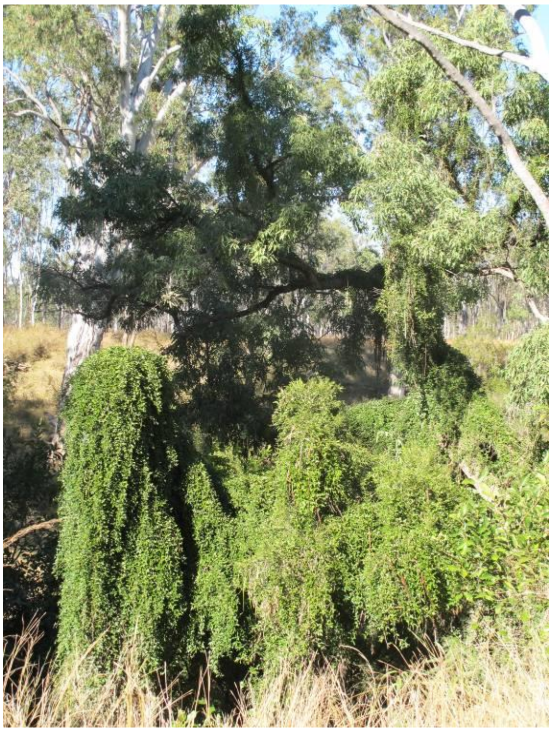

Figure 18: Infestation of cat's claw vine – *Macfadyena unguis-cati* – on the Palm Tree Creek between Jamberoo and Gwambegwine. This species has the potential to seriously degrade the health of the Palm Tree Creek riparian ecosystem and its treatment should be made a priority. Images: Jason Halford.

Whist the introduced species *Parthenium hysterophorus* (parthenium weed) was not recorded during the current survey, the species is recorded in the local area and recent reports have indicated it to be occurring in the upper Palm Tree catchment. Parthenium weed is a Weed of National Significance and is a Class 2 declared species under Queensland Government Legislation and as such reasonable efforts must be made by land managers to keep their land parthenium weed free.

Importantly, no ponded pasture species were recorded in any wetlands surveyed in this project. The introduced ponded pasture species olive hymenachne, para grass, and aleman grass are serious ecological threats to wetland and floodplain ecology. Olive hymenachne resides on the declared plant list within New South Wales, Queensland, Northern Territory and Western Australia. Aleman grass is also declared a noxious weed in New South Wales. Federally, olive hymenachne is listed as a "Weed of National Significance" while both olive hymenachne and para grass are listed as *Environment Protection and Biodiversity Conservation Act 1999* key threatening processes.

Olive hymenachne and para grass have been described as robust perennials that increase biomass, reduce plant species richness and change vegetation structure. These changes in plant ecology ultimately lead to changes in the abundance of insect species, native and introduced fish species and a deterioration in habitat for wetland bird species (Arthington et al. 1983; Bunn et al. 1998; Houston and Duivenvoorden 2002; Wearne et al. 2010; Wearne et al. 2013). Proliferation of para grass and associated increases in biomass alters hydrology via a reduction in flow rates, increases sediment deposition and restricts oxygen intake into fine sediments (Bunn et al. 1998). Furthermore, the large volumes of biomass generated by para grass leads to increased fuel loads that can ultimately lead to an increase in fire intensity under dry conditions (Douglas and O'Connor 2004). Olive hymenachne is a fecund species that establishes via germinated seed and vegetative material (Wearne et al. 2013). The seed is long-lived in the seed bank (Campbell et al. 2009) and the species is difficult to control effectively with herbicide due to site inaccessibility and the restricted use of herbicide in wetland environments (Wearne et al. 2010). Comparatively little research has been carried out on aleman grass specifically, however all three species have the ability to invade and seriously degrade wetland habitats (Rea and Storrs 1999).

The absence of introduced ponded pasture species in this survey is surprising, particularly as the practice of ponded pasture grazing is well established in the Fitzroy Basin and the use of these species widespread (for examples see Houston and Duivenvoorden 2002; Grice et al. 2011). Herbarium records for these three species from within the Dawson River catchment identify the closest proximity of each species to the study area as para grass at Theodore (approximately 140km downstream) collected in 2004, with olive hymenachne and aleman grass collected at a property west of Moura (approximately 220km downstream) in 1987 (Australia's Virtual Herbarium 2014). Although downstream from the Palm Tree and Robinson Creek wetlands, these locations are in considerably close proximity, particularly the occurrence of para grass at Theodore. Para grass infests irrigation channels in sugar cane plantations in the tropics (Bunn et al. 1998) and is likely to be taking advantage of the readily available water in the Theodore Irrigation Area. There is considerable potential for this species to be transported unintentionally into the Palm Tree and Robinson Creek catchments via the movement of livestock, vehicles and farming equipment.

Although infestations of ponded pasture species are extensive in the Fitzroy Basin, it is clear these invasive species are yet to reach their full potential in terms of distribution. Ensemble model outputs generated to assess the risk to catchments of invasion by olive hymenachne by Wearne et al. (2013) identified the Fitzroy Basin to be at high risk of successful establishment. Wearne et al. (2013) also noted an increased risk of further spread of olive hymenachne within the Fitzroy Basin due to extensive areas of suitable habitat. Grice et al. (2011) recommend areas in the Fitzroy Basin free of olive hymenachne that are of high environmental, economic or cultural value be prioritised for protection against this species introduction. The absence of introduced pasture species in this survey is perhaps a reflection of the value of these wetlands and the native pastures they support, to the landholders in the area. However, the absence of these introduced species from this survey does not exclude their absence from the Palm Tree and Robinson Creek catchments more broadly and a thorough investigation of wetlands not visited in the current survey is required to confirm the absence of these invasive species.

4.2.3 Grazing and Hydrological Alterations

The Palm Tree and Robinson Creek wetlands are valuable resources to the landholders that manage them in terms of their water and food supply to stock. Surveys showed little difference in species diversity between wetlands that were heavily grazed and those that had been rested or where cattle were excluded. There was also no obvious difference in the presence of exotic weed species between heavily and lightly grazed wetlands. Whilst it appeared evident that there was less biomass and a greater cover of bare ground in some heavily grazed wetlands, these aspects were not measured in this survey and are therefore not quantifiable. Interestingly, there was no visible evidence of overgrazing in the reedy swamps dominated by perennial *Eleocharis* species. However it should be noted that some of the shallower wetlands showed heavy trampling at the shoreline. Such trampling is likely to have some negative impact to wetland vegetation.

Furthermore, anecdotal evidence suggests some of the larger Robinson Creek lakes are becoming shallower, presumably through siltation. Although siltation may be a component of natural process via flood deposition, it also may be contributed to by excessive land clearing, stocking rates and cultivation. Sensible stocking rates and paddock rotation are recommended to ensure the long-term sustainable use and health of these wetlands by limiting erosive processes and loss of valuable top soil. As mentioned previously, allowing native perennials to continue to dominate certain vegetation groups through reduced stocking rates may also assist in the control of the serious weed lippia. Also, implementing sustainable stocking rates may assist in maintaining wetland diversity by reducing external pressures on species that may struggle to adapt to the effects of climate change. For example, it is feasible that some aquatic species may have difficulties reproducing either vegetatively or from the soil seed bank if droughts become more frequent over longer durations as a result of climate change. This pressure will be magnified by a reduction in viable seed banks if these species are overgrazed and unable to reach their reproductive potential in good seasons.

Four of the wetlands surveyed showed evidence of being hydrologically altered to various extents at some time in the past. Minor alterations are likely to have been made to some wetlands historically to ensure these valuable water storage assets are maintained. There were no obvious differences in wetland vegetation composition or species diversity below the current tree line, between wetlands that were noted to be altered and those that weren't. Whilst the vegetation of these previously altered wetlands show no obvious detrimental effects from past practices, any alterations to the hydrology of these flood plains (and those of the adjacent Dawson River catchment into which they drain) must be discouraged to ensure the long-term health of these wetland resources. This is also true for any large-scale impoundments, resource extraction or other developments planned for the future. Such developments could have serious long-term consequences for the hydrological function and health of these floodplains and their wetlands. For example, large-scale alterations and impoundments, such as the proposed Nathan Dam adjacently downstream in the Dawson Valley is likely to have wide ranging negative impacts on floodplain and wetland health within the surrounding catchments (see Fensham 1998; Pollock et al. 2004) and may provide a substantially larger habitat area for the invasive weed lippia.

Figure 19: The Palm Tree and Robinson Creek wetlands are a valuable resource for local landholders. Appropriate stocking rates will continue to ensure the sustainable, on-going use of these resources into the future. Image: J. Halford.

5 Future Recommendations

5.1 Control of Exotic Species

Infestations of cat's claw vine along the Palm Tree Creek are a major concern. If left untreated, these infestations are likely to result in the death of riparian vegetation and a major decline in the health of the waterway. With seed dispersed by wind and water new outbreaks are likely along the Palm Tree Creek floodplain and wetland system. Removal of cat's claw vine is problematic and labour intensive and becomes more challenging as the infestation advances. It is therefore recommended as a priority, that a vegetation management contractor experienced in the treatment of cat's claw be engaged to survey the Palm Tree Creek to determine the full extent of the infestation prior to the treatment of this invasive weed. In treatment, the main priority will be to remove above ground biomass to free existing native vegetation and limit the capability of cat's claw to reproduce. Due to the presence of underground tubers, cat's claw vine is an extremely difficult plant to destroy. It should therefore be expected that follow up treatment be required to treat any resprouting. Landholders should also be engaged for further monitoring of new outbreaks. Feral pigs have become a major pest issue across the broader landscape. Within the Palm Tree and Robinson Creek wetlands their numbers have rapidly increased over recent decades (Adam Clark pers. comm.). Where possible, an active feral pig eradication program should be employed to control pig numbers. The presence of lippia is a concern for the on-going health and function of the Palm Tree Creek and Robinson Creek Wetland systems. Although this invasive species has had little impact on these wetlands to date, the potential damage this plant can cause to the ecology and productivity within these wetlands is evident in what has occurred in the wetlands of the Murray-Darling. It is therefore recommended that this species continue to be monitored.

5.2 Ongoing Monitoring of Wetland Health

This flora survey clearly identified eight vegetation groups within the Palm Tree and Robinson Creek wetlands, influenced by water depth, soil conductivity and slope. However, this survey was limited by the number of wetlands accessed with each of these visited only once. These spatial and temporal limitations restrict insights into the broader ecological function of the Palm Tree and Robinson Creek wetland complex. To gain a deeper understanding of Palm Tree and Robinson Creek wetland vegetation, studies need to be conducted on seasonal and decadal timeframes to understand wetland response to more predictable short-term and less predictable long-term climatic shifts. Further, more long-term studies are required to identify shifts in vegetation zonation, the fluctuation of native and exotic species, and importantly, to monitor overall wetland function and health. The knowledge gained from such surveys can further inform landholders on the best approaches to providing long-term, sustainable management of the Palm Tree and Robinson Creek wetlands. Although this flora survey failed to identify any wetland plant species requiring specific conservation attention, the importance of these semi-arid wetlands certainly lies in their number and therefore their significance as habitat for local and migratory fauna. The reliance on these wetlands by local and migratory species highlights the importance of these wetlands at both the regional and national scale. Indeed further investigations that focus on the importance of the Palm Tree and Robinson Creek wetlands to the fauna species that rely on them would also be extremely beneficial, particularly as these species begin to face greater threats from climate change.

Figure 20: The Palm Tree and Robinson Creek wetlands are undoubtedly extremely important resources for local and migratory wildlife. Ongoing monitoring of these wetlands will assist in the long-term sustainable management of these complex systems. Image: J. Halford.

6 Conclusion

The Palm Tree and Robinson Creek wetlands are considered important wetlands by the Australian Government. Whilst the vegetation of these wetlands is diverse, their uniqueness lies in their extent in numbers, which undoubtedly contributes to their importance to native wildlife. The wetlands and associated floodplains of the Palm Tree and Robinson Creeks have been and continue to be a focal point of Indigenous and European land use within the area and the Near Threatened Carnarvon fan palm (*Livistona nitida*) stands as a backdrop to these oases in a semi-arid landscape. The continued sustainable management of the wetlands of the Palm Tree and Robinson Creeks must remain a priority for conservation in the Taroom District, for all to enjoy into the future.

Figure 21: Sustainable management of wetlands such as this at Jamberoo must remain a regional conservation priority into the future. Image: J. Halford

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Avian Fauna Report

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Our country, Our future

Birdlife of the Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by Allan Briggs, Secretary of BirdLife Capricornia, for Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

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This report was prepared on behalf of FBA by BirdLife Capricornia.

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Summary

Palm Creek and Robinson Creek wetlands are listed on the Directory of Important Wetlands in Australia and form part of the Fitzroy River catchment. Fifteen sites were selected across the geographical footprint of the wetlands to provide a representative sample of the whole. Three bird surveys were conducted in April, June and October of 2013 by a team of four experienced bird watchers from BirdLife Capricornia. Data was entered into a spread sheet for each survey to provide individual data and combined data for the sites across the study area.

A desk top audit indicated a possible 230 species for the study area with a total of 142 being recorded over the three surveys. This result is not surprising given the small sample size and number of surveys. The largest abundance of birds across the study area was recorded in June with some 9888 birds. If this is extrapolated across the whole study area it could mean that somewhere in the order of 100,000 birds are using the extended wetland system.

Five threatened species were recorded as well as two introduced species, eight resident and one migratory shorebird species. There was no species that met the 1% criteria for congregatory water birds. Given the small sample size, it is expected that at least one species would meet this criterion if the collected data was extrapolated across all wetlands in the study area.

Some birds such as the Black Swan were seen in the process of breeding and others with chicks or juveniles showed the results of successful breeding. However, the ephemeral nature of many of the wetlands would mean that only a small number would provide suitable breeding habitat during times of drought.

Overall the surveys were successful in providing useful data for an area which is poorly known with regard to bird species and identified the wetlands as being important for waterbirds, shorebirds, and woodland birds.

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Graham Durant

Allan Briggs

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Ann Hobson (June and October)

Melanie Simmons (June)

Property owners in the Robinson Creek and Palm Creek catchments who gave permission for access to wetlands on their properties so that surveys could take place.

Waunui

Bimbadeen

Robinson Creek

Broadmere

Belle Eau

Lakefield

Jamberoo

Wythburn

Huntington/Waterton

Box Tree

Glossary and Acronyms

EPBC	Environment Protection and Biodiversity Conservation Act, a federal government Act of Parliament
ENSO	El Nino Southern Oscillation
NCA	Nature Conservation Act, a Queensland state government Act of Parliament
Ramsar	The Convention on Wetlands of International Importance, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

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1 Introduction

The project involved a bird survey of the Robinson and Palm Creeks wetland areas listed on the Australian Directory of Important Wetlands. Both creeks drain into the Dawson River and form part of the Fitzroy River catchment.

The project outcomes included the following;

- Desktop review of existing data
- On-ground site selection and mapping
- Three surveys
    - April – three day survey
    - June – three day survey
    - October – three day survey
    - Compilation of data from the three surveys into a technical report

Each survey took place at a different time of the year to coincide with a) post wet season b) winter migrations c) spring migrations and the dry period before summer rain.

This study forms one component of a broader project to document the ecological and hydrological character of the Palm Tree and Robinson Creeks Wetlands. In addition to the present report on avian fauna of the wetlands, other studies have recorded the terrestrial and aquatic flora and fauna, and hydrological and social values of the wetlands. The results and recommendations of this report, together with the other studies, will form a technical report for the wetlands and guide the development of wetland guidelines for landholders and natural resource managers.

Limitations

Initially Gwambegwine had given permission for access to the property and as a result sites were selected there. Subsequently this permission was withdrawn but we were still able to survey the sites from the road. The requirement to wash and clean the vehicle to limit the spread of Parthenium was carried out for each survey but certificates of compliance from the washdown facilty at Taroom were not available and this resulted in our inability to access Box Tree in June. However, the use of a self-assessment Weed Hygiene Declaration allowed us to survey Box Tree in October. The Lake on Huntington/Waterton was surveyed in April and June but access permission was withdrawn and we were only able to complete a partial survey from the road in October.

Given that 15 sites were surveyed, 13 wetlands and 2 riparian, and that the Directory of Important Wetlands identifies 155 wetlands across the study area, less than 10% of the wetland system was surveyed. This means that the data collected is only representative of the bird species found and other species may be present that were not recorded.

2 Methods

The methodology consisted of choosing a range of sites across the project area that would provide not only a good geographical spread of sites but also provide a range of lacustrine, palustrine and riparian sites that would be representative of the study area. This process was limited to some degree by the property owners who had given permission for access to do bird surveys. In some cases where a property owner had not given permission we were able to survey wetlands from the roadside. The net result was a total of 15 sites, three of which were palustrine, ten of which were lacustrine and two of which were riparian. In addition, a record of incidental sightings was kept when travelling between sites. This spread of sites extended from Robinson Creek and Broadmere in the south west, Box Tree in the south East, Jamberoo in the north east and Gwambegwine in the north west. Refer to Appendix 2 for representative photos of sites.

Separate data was kept for the environs around Taroom and Glebe Weir as these sites were on the Dawson River. Although outside of the study area it was thought that data from the river itself would provide information about birds that may be in the area but not using the wetlands.

Survey methods consisted of the following;

- Wetland sites

  These were surveyed by fixing an approximate point in the middle of a wetland and surveying to the fringing vegetation using high powered telescopes. Species flying over the wetlands were identified using binoculars and also recorded. Both bird species and abundance were counted and recorded. No time limit was placed upon the survey since completeness and accuracy were the main considerations. Two volunteers surveyed the wetlands with telescopes and confirmed species identification by consultation and where necessary reference to a field guide. The surrounding grassland and woodland were surveyed by another two volunteers using binoculars. All data was combined and recorded in a spread sheet.

- Riparian sites

  A distance of 500 metres in each direction from a central point was surveyed. Two volunteers in each direction and to avoid over counting only the highest count of any species was recorded.

- Incidental sightings

  Incidental sightings were recorded while travelling between sites on Glenhaughton Road, Ghinghinda Road and Flagstaff Road. Most birds could be identified while travelling but in cases where identification needed confirmation the vehicle would stop and all volunteers would sight the bird or birds and confirm identification.

It was not possible to survey Box Tree in June due to the requirement for a vehicle inspection certificate which could not be obtained. The Lake was not surveyed in October because the property owners withdrew access permission. Robinson Creek was only surveyed in October.

Table 1: Sites and coordinates

	Location	South	East
1	Lake Murphy Public access from car park Lacustrine site that was the largest wetland surveyed	25, 28, 43	149, 39, 14
2	Bimbadeen riparian site Access off Glenaughton Road to Robinson Creek Riparian site along Robinson Creek	25, 29,07	149, 36, 05
3	Waunui Lagoon Access off Glenaughton Rd Paulstrine site quite small and shallow	25, 29 ,06	149, 36, 13
4	Broadmere lagoon Access through fence off Broadmere Rd Palustrine site	25, 29, 38	149,30, 16
5	Belle Eau Lagoon Surveyed from the roadside off Ghinghinda Road Lacustrine site quite small and shallow	25, 20, 21	149, 44, 07
6	Lakefield Lagoon Access via dirt road on East side of lake, park and walk in. Lacustrine site	25, 15, 03	149° 42' 26
7	Lakefield Lake View from vantage point on side of Ghinghinda Road Lacustrine site	25,13,37	149,42,16
8	Jamberoo Lagoon Access through fence off Ghinghinda Road Lacustrine site	25, 13, 13	149, 42, 05
9	Gwambegwine riparian site Access via Fitzroy Development Road, walk along creek	25, 16, 23	149, 36, 17
10	Gwambegwine white wine lagoon View from vantage point off Fitzroy Development Road Lacustrine site	25, 15, 54	149, 35, 33
11	Gwambegwine red wine lagoon View from vantage point off Fitzroy Development Road Lacustrine site	25,14,00	149,34,47
12	Wythburn Lagoon Access through gate off Flagstaff Road Lacustrine site	25, 19, 40	149, 44, 60
13	The Lake Access through fence off Flagstaff Road and walk down to lagoon Lacustrine site	25, 21, 13	149, 47, 57
14	Box Tree Lagoon Access off Leichardt Highway Lacustrine site	25, 26, 12	149, 48, 30
15	Robinson Creek Access off Glenhaughton Road Palustrine site	25,27,32	149,32,54

3 Results

The following three sets of figures and tables summarise the data for each of the three surveys undertaken in April, June and October. For each survey the number of species by site and the number of birds by site are shown in graphical format so that the sites where most species and most birds were recorded can easily be seen. In addition a summary table of species and abundance has been provided to show the exact numbers that were recorded for each site.

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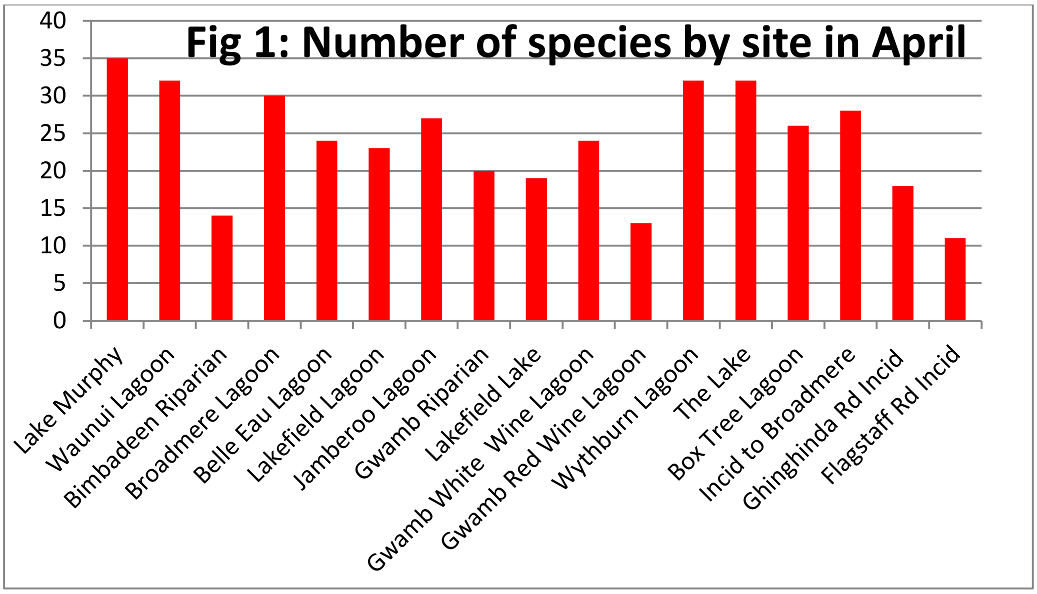
April 2013



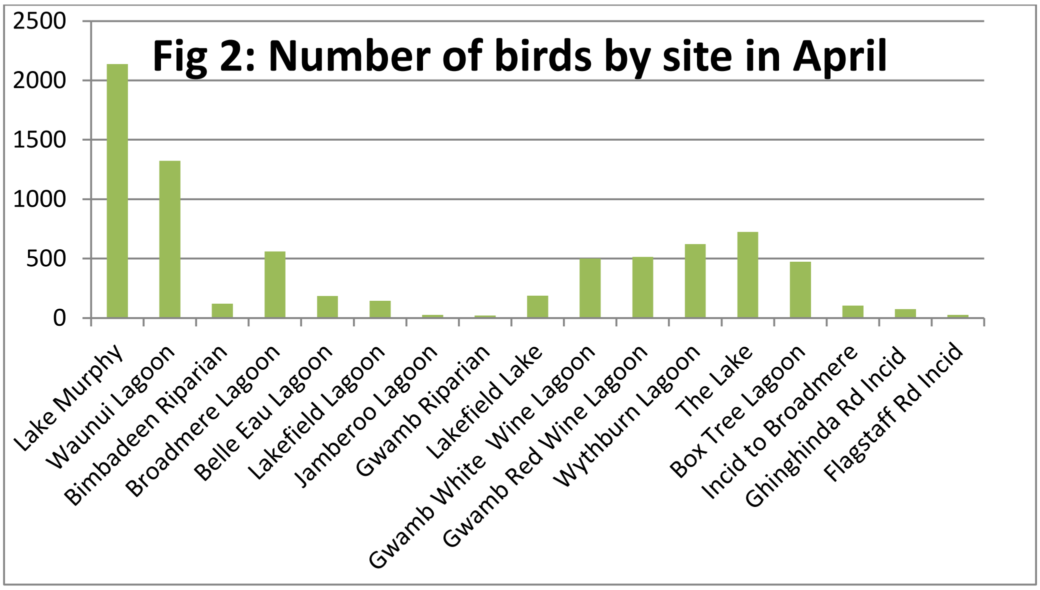
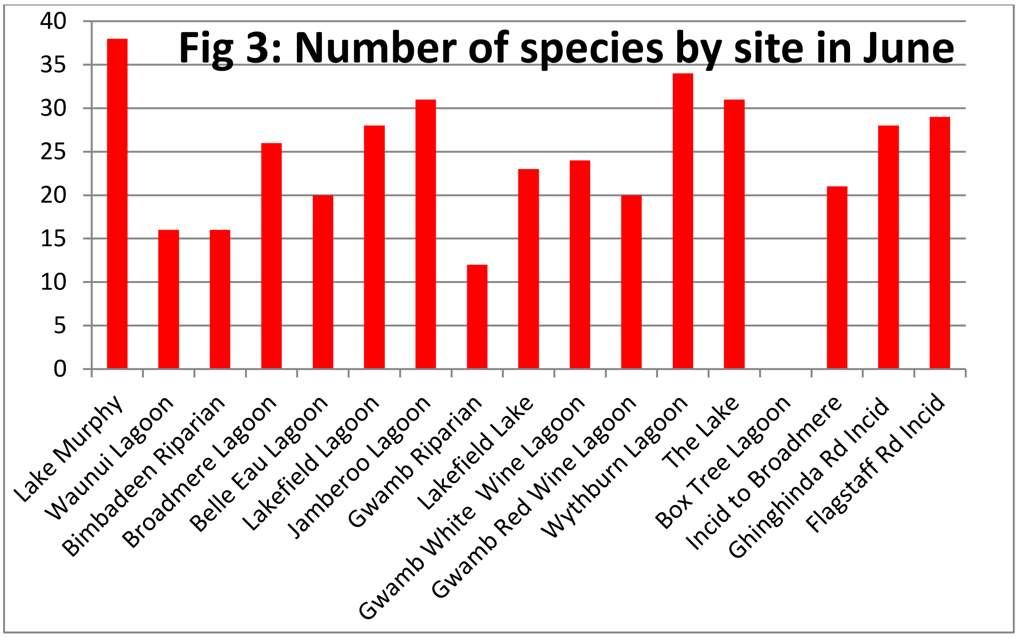


Table 2: Summary of results from April 2013

	Lake Murphy	Waunui Lagoon	Bimbadeen Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total birds	Total species
Total number of birds	2138	1324	120	559	186	146	27	20	188	502	515	623	725	474	105	75	26	8343	103
Total number of species	35	32	14	30	24	23	27	20	19	24	13	32	32	26	28	18	11		

June 2013



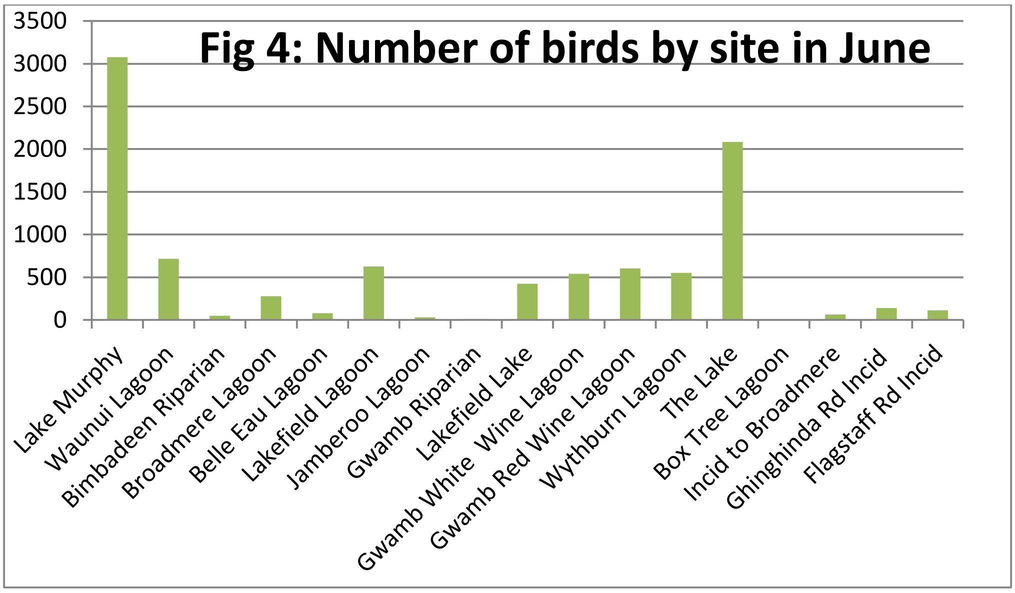
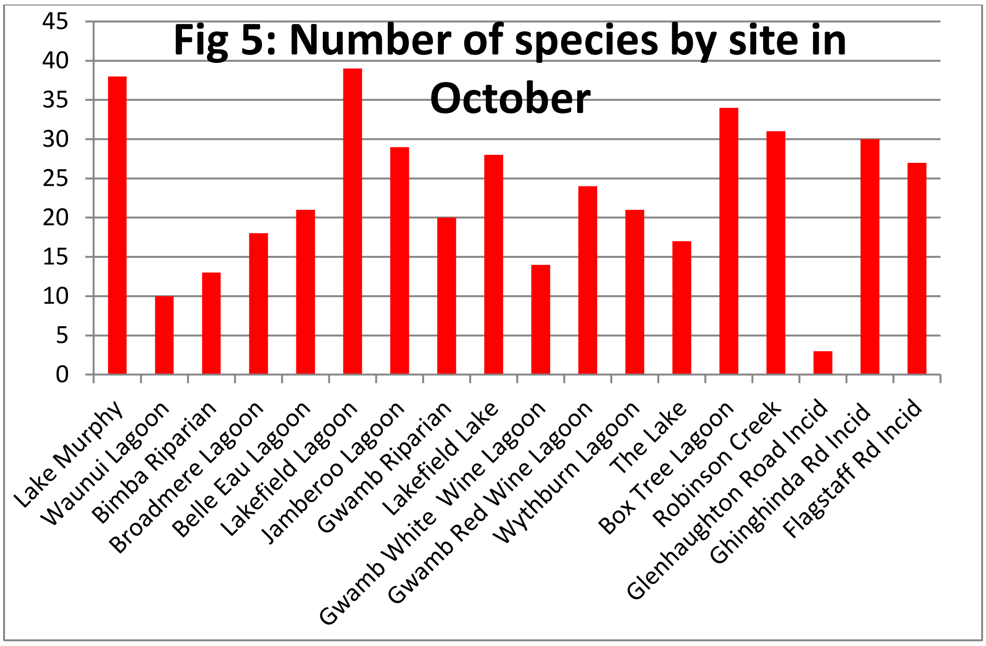


Table 3: Summary of results from June 2013

	Lake Murphy	Waunui Lagoon	Bimbadeen Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total birds	Total Species
Total number of birds	3077	718	50	277	81	625	31	12	425	540	604	552	2084	0	63	138	113	9888	94
Total number of species	38	16	16	26	20	28	31	12	23	24	20	34	31	0	21	28	29		

October 2013



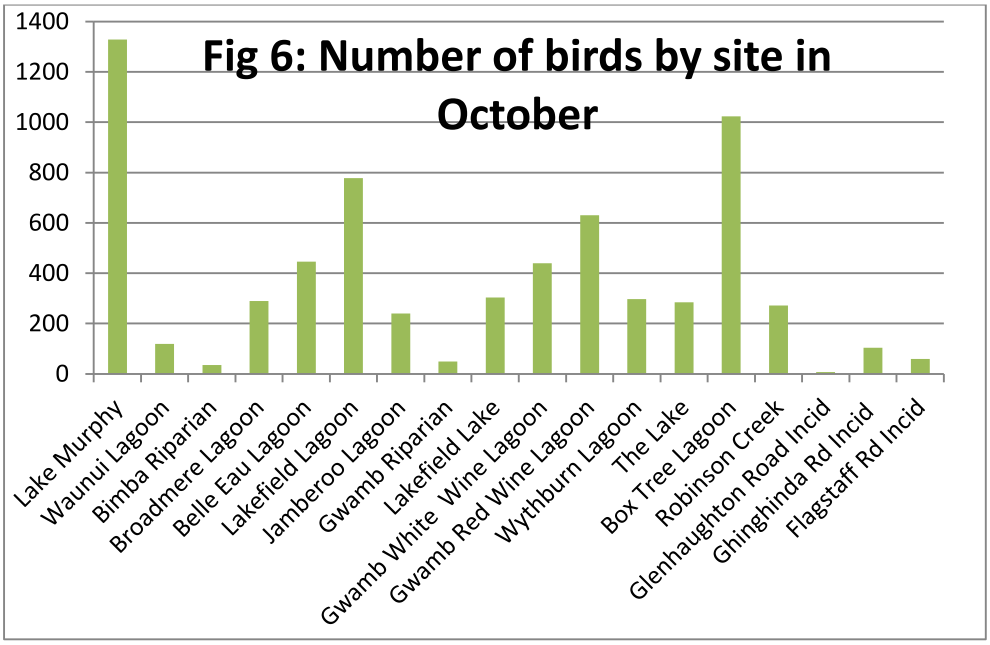
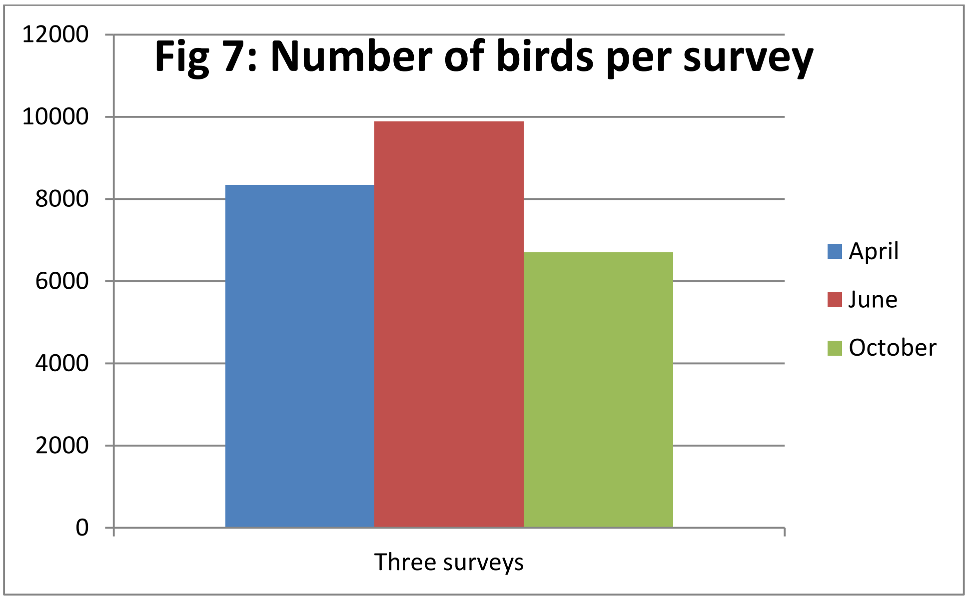


Table 4: Summary of results from October 2013

	Lake Murphy	Waunui Lagoon	Bimba Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Robinson Creek	Glenhaughton Road Incid	Ghinghinda Rd Incid	Flagstaff Rd Incid	Number of birds	Species
Total number of birds	1328	119	35	290	446	778	240	49	303	440	630	297	285	1024	272	7	104	60	6707	111
Total number of species	38	10	13	18	21	39	29	20	28	14	24	21	17	34	31	3	30	27		

Summary of species and abundance over three surveys

The following two tables show a comparison of the number of species and number of birds seen for each of the three surveys. This allows the differences between each survey over the course of the year to be seen. June had the lowest number of species but the largest number of birds while October had the largest number of species but the lowest number of birds.



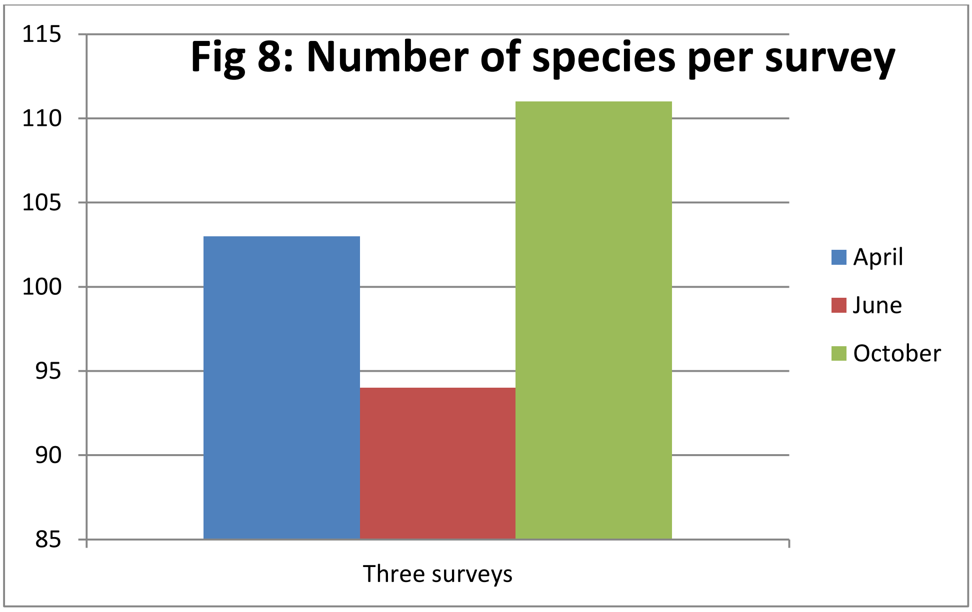


Table 5: Threatened species recorded in study area

The value of identifying threatened species and their location is to determine if any of the wetlands surveyed are providing refuge habitat that may need targeted management. While some threatened species were identified none were of a critical nature.

Species	EPBC Status	NCA status	Seen
Squatter Pigeon *Geophaps scripta scripta*	Vulnerable	Vulnerable	Gwambegwine Red Wine Lagoon
Black-necked Stork *Ephippiorhynchus asiaticus*	Not listed	Near Threatened	Lake Murphy Waunui Lagoon Gwambegwine White Wine Lagoon Ghinghinda Road
Cotton Pygmy-goose *Nettapus coromandelianus*	Not listed	Near Threatened	Broadmere Lagoon Jamberoo Lagoon Lakefield Lake Gwambegwine Red Wine Lagoon Gwambegwine White Wine Lagoon Wythburn Lagoon The Lake
Freckled Duck *Stictonetta naevosa*	Not listed	Near Threatened	Broadmere Lagoon The Lake
Turquoise Parrot *Neophema pulchella*	Not listed	Near Threatened	Robinson Creek

Table 6: Introduced species recorded in the study area

Introduced species often displace native species by competing for nest sites and food. The two species identified here are of particular concern since they are considered to be invasive pest species.

Species	EPBC Status	NCA status	Seen
Common Myna *Sturnus tristis*	Introduced	Introduced	Box Tree Bimbadeen riparian
Common Starling *Sturnus vulgaris*	Introduced	Introduced	Bimbadeen riparian

Table 7: Wetland conditions

Wetland conditions varied through the year over the duration of the three surveys with all wetlands being full to overflowing in April and some nearly dry in October. Generally speaking birds will disperse when habitat is plentiful and will converge on remaining habitat as wetlands dry up and water levels recede. However, over time food resources become depleted in a drying wetland and birds will then start to disperse again looking for alternative food sources.

	Lake Murphy	Waunui Lagoon	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Lakefield Lake	Gwamb White Wine	Gwamb Red Wine	Wythburn Lagoon	The Lake	Box Tree Lagoon	Robinson Creek
Wetland in April % of water	100	100	100	100	100	100	100	100	100	100	100	100	
Wetland in June % of water	90	80	90	80	95	80	80	80	90	80	90		
Wetland in October % oif water	60	10	10	40	90	40	50	30	40	20	90	20	80

Table 8: Wetland habitat and size

Some basic details of the habitat found at each site and the approximate size are given below.

	Location	Habitat	Length	Width
1	Lake Murphy Public access from car park Lacustrine site	Deep water with shallow edges	1.5 kms	1.3 kms
2	Bimbadeen riparian site along Robinson Creek Access from Glenaughton Road Riparian site	Riparian vegetation along a deep creek	500 metres	
3	Waunui Lagoon Access via Glenaughton Rd Palustrine site	Shallow water with shallow muddy edges	1.24kms	750 metres
4	Broadmere lagoon Access from roadside off Broadmere Rd Palustrine site	Deep water with dead trees along edge and emergent vegetation on shallow north side	1.4 kms	750 metres
5	Belle Eau Lagoon Access from roadside off Ginghinda Rd, Lacustrine site	Shallow water with shallow muddy edges ideal for dotterels	600 metres	500 metres
6	Lakefield Lagoon Access from roadside off Ginghinda Rd Lacustrine site	Deep water steep banks and little in the way of shallow edges	1.1km	750 metres
7	Lakefield Lake Access from roadside off Fitzroy Development Rd Lacustrine site	Shallow lagoon covered in *Nyphoides indica* and blue water lilies, ideal for pygmy geese	880 metres	200 metres

	Location	Habitat	Length	Width
8	Jamberoo Lagoon Access via Ghinghinda Road, Lacustrine site	Deep water at northern end with shallow edges at southern end and covered in blue water lilies	1.2km	500 metres
9	Gwambegwine riparian site Access via Fitzroy Development Road	Riparian with mature woodland on all sides	500 metres	
10	Gwambegwine white wine lagoon. Access via Fitzroy Development Road, Lacustrine site	Deep water with little emergent vegetation	800 metres	120 metres
11	Gwambegwine red wine lagoon Access via Fitzroy Development Road. Lacustrine site	Quite shallow with muddy edges	600 metres	200 metres
12	Wythburn Lagoon Access via Wythburn Road. Lacustrine site	Deep water with shallow edges at both ends	1.5kms	600 metres
13	The Lake Access via Flagstaff Rd. Lacustrine site	Deep water with large areas of blue water lilies	1.2km	800 metres
14	Box Tree Lagoon Access opposite Glebe Weir Rd off Leichardt Highway or via main access closer to Taroom Lacustrine site	Deep water at northern end with shallow edges on southern end with considerable areas of blue water lily	1.5kms	0.5kms
15	Robinson Creek Lagoon Access from Glenaughton Road Palustrine site	Deep water at southern end and quite shallow at northern end with some small islands. No emergent vegetation.	600 metres	200 metres

Note: Photographs of the three habitat types of Lacustrine, Palustrine and Riparian can be found in Appendix 2.

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Table 9: Species list for study area

This table identifies the individual species that were seen at all sites across the three surveys. Bird species and abundance for each site is provided in Appendix 3.

Family	Species
Emu, Mound Builders and Quail	Emu
	Brown Quail
Swans, Geese, Ducks and Grebes	Pacific Black Duck
	Australian Grebe
	Black Swan
	Hardhead
	Chestnut Teal
	Wandering Whistling Duck
	Grey Teal
	Plumed Whistling Duck
	Green Pygmy Goose
	Cotton Pygmy Goose
	Australasian Shoveler
	Great Crested Grebe
	Australian Wood Duck
	Freckled duck
	Pink-eared Duck
	Magpie Goose
	Eurasian Coot
Gannets, Cormorants Pelican	Great Cormorant
	Darter
	Little Pied Cormorant
	Pied Cormorant
	Little Black Cormorant
	Australian Pelican
Herons, Ibis, Spoonbills	White-faced Heron
	Royal Spoonbill
	Yellow-billed Spoonbill
	Little Egret
	Intermediate Egret
	Great Egret
	Glossy Ibis
	Cattle Egret
	Straw-necked Ibis
	Australian White Ibis
	White-necked Heron
	Black-necked Stork

Family	Species
Birds of Prey	Nankeen Kestrel
	Wedge-tailed Eagle
	White-bellied Sea Eagle
	Whistling Kite
	Black-shouldered Kite
	Osprey
	Brown Falcon
	Spotted Harrier
	Collared Sparrowhawk
	Black Kite
	Black-shouldered Kite
Brolga, Crakes, Rails	Black-tailed Native Hen
	Brolga
	Dusky Moorhen
	Spotless Crake
	Purple Swamphen
Bustard, Button Quail	Australian Bustard
Waders	Masked Lapwing
	Black-winged Stilt
	Comb-crested Jacana
	Red-kneed Dotterel
	Red-necked Avocet
	Australian Pratincole
	Marsh Sandpiper
	Black-fronted Dotterel
Gulls, Terns	Whiskered Tern
	Gull-billed Tern
	Caspian Tern
Pigeons, Doves	Crested Pigeon
	Peaceful Dove
	Bar-shouldered Dove
	Squatter Pigeon

Family	Species
Cockatoos, Parrots, Rosella	Sulphur-crested Cockatoo
	Budgerigar
	Red-winged Parrot
	Cockatiel
	Pale Headed Rosella
	Rainbow Lorikeet
	Scaly-breasted Lorikeet
	Turquoise Parrot
	Red-rumped Parrot
	Galah
Cuckoos	Brush Cuckoo
	Pheasant coucal
	Channel-bill Cuckoo
Night Birds	Southern Boobook
	Barking Owl
Swifts, Kingfishers	Laughing Kookaburra
	Sacred Kingfisher
	Blue-winged Kookaburra
	Rainbow Bee-eater
	Dollarbird
	Forest Kingfisher
Pittas, Lyrebirds, Treecreepers	
Wrens, Pardalotes Gerygone	Red-backed Fairy Wren
	White-throated Gerygone
	Inland Thornbill
	Yellow Thornbill
	Varied Sittella
	Yellow-rumped Thornbill
	Buff-rumped Thornbill
Scrubwrens, Allies	Striated Pardalote
	Weebill

Family	Species
Honeyeaters	Blue-faced Honeyeater
	Little Friarbird
	White-throated Honeyeater
	Striped Honeyeater
	Noisy Friarbird
	Yellow -throated Miner
	Noisy Miner
	White-eared Honeyeater
	Brown Honeyeater
	White-plumed Honeyeater
Chats, Robins	Jackie Winter
	Red-capped Robin
Babblers, Whipbird	Grey-crowned Babbler
Quail Thrush & Allies	
Whistlers, Shrike Thrush	Rufous Whistler
	Grey-shrike Thrush
	White-winged Triller
Magpie Lark, Flycatchers, Fantail	Grey Fantail
	Restless Flycatcher
	Magpie Lark
	Leaden Flycatcher
Cuckoo Shrike, Oriole Figbird	Australasian Figbird
	Black-faced Cuckoo Shrike
	White-bellied Cuckoo Shrike
	Olive-backed Oriole
Woodswallows	White-breasted Woodswallow

Family	Species
Magpie, Butcherbirds Birds of Paradise	Grey Butcherbird
	Australian Magpie
	Pied Butcherbird
	Pied Currawong
	Torresian Crow
Ravens, Mudnesters	White-winged Chough
Bowerbirds, Larks, Pipits & Wagtails	Willie Wagtail
	Apostlebird
	Australasian Pipit
	Horsfield's Bushlark
	Spotted Bowerbird
Sparrows, Finches	Plum-headed Finch
	Double-barred Finch
Sunbird, Mistletoe Bird	
Swallows, Bulbuls Martins, Silvereye	Welcome Swallow
	Tree Martin
Warblers, Thrushes	Golden-headed Cisticola
	Common Starling
Myna, Starling	Common Myna

Total number of species recorded in the study area over three surveys = 142

Note: A list of scientific binomial bird species names are provided in Appendix 1. Bird species and abundance for each site are provided in Appendix 3.

Table 10: Breakdown of bird groups

Birds are conveniently grouped into families which have common features, habitat requirements, behaviour and food requirements. This table shows the number of species from each group that were seen over the three surveys.

Bird group	Species seen
Waterbirds	40
Shorebirds (migratory)	1
Shorebirds (resident)	8
Birds of Prey	11
Seabirds	3
Woodland birds	75
Night birds	2
Introduced birds	2

Table 11: Additional species recorded for Taroom and Glebe Weir

The study area was defined as those wetlands bordering Robinson and Palm Tree Creeks and all of the survey sites were selected from that area. However, it was considered useful to include species seen at Taroom and Glebe Weir which although outside the study area have the potential to be seen within the study area because of its proximity. The table shows 10 such species.

Species	Seen
Nankeen Night Heron	Glebe Weir
House Sparrow	Taroom
Superb Fairy-wren	Taroom
Buff-banded Rail	Taroom
Fan-tailed cuckoo	Glebe Weir
Pallid Cuckoo	Glebe Weir
Brown-headed Honeyeater	Glebe Weir
Rufous Fantail	Taroom
Fairy Martin	Taroom
Common Koel	Taroom

4 Discussion

It would be pertinent to note that conditions at all wetlands in April and June were excellent due to the wet start to the year. Wetlands were full or nearly full with some having good fringing reed beds, floating and emergent vegetation. Those wetlands with shallow trailing edges were also providing good food for wading birds. In contrast the conditions for the October survey were very dry with some wetlands totally dry and others with only a small percentage of water remaining (see Table 7). This change over time produced some interesting data (see Figs 7 and 8). The highest abundance of birds occurred in June with nearly 10,000 counted and the lowest in October with just over 6,000 counted. Combine this with the highest number of species recorded in October at 111 and the lowest number in June at 94. This can be explained by the fact that when conditions are good birds will disperse across the landscape and when conditions deteriorate they will congregate around the remaining good habitat.

Desktop review of existing data

By consulting Birdata, the online database provided by BirdLife Australia, a total of 230 species have been recorded historically for the greater Taroom area and the study area. However, there has not been a great deal of survey data recorded for the study area with most surveys being done around Taroom and the Leichardt Highway. Over the three surveys 142 species were recorded for the study area and 152 species for the greater Taroom area. This indicates that some 88 species that have been recorded historically were not recorded for the study area and 78 species were not recorded for the greater Taroom area. For such a small set of data this is not surprising as surveys were not conducted through all months of the year and were only conducted at a small percentage of the possible sites. Even so some 66% of birds that were recorded historically were seen on the surveys.

A search was conducted to locate other sources of data that may be useful and the following was found.

Crossman, D.G. and Reimer, D.S. (1986). Mammals, birds, reptiles and amphibians of the Taroom Shire, central Queensland. Qd. J. Agric. Anim. Sci., 43:55-72. A survey from 1977 to 1979 located 48 species of mammals, 209 of birds, 52 of reptiles and 19 of amphibians. Habitat types and estimates of abundance are given.

The 209 species of birds was consistent with the records from Birdata. However, this survey consisted of twenty trips averaging seven days with a total of 290 survey days between 1977 and 1979. Even though birds were only part of the survey it does represent a more comprehensive survey over a longer time frame. Unfortunately the report does not identify the specific sites surveyed so it is difficult to make direct comparisons.

In 1844 Gilbert passed through the area with the Ludwig Leichardt expedition to Port Essington and he recorded 58 species. Most of these were seen but one, the Paradise Parrot, is now extinct and others such as the Crimson Finch and Star Finch no longer occur in the region.

Survey sample size in comparison to the whole study area

The wetlands that were surveyed were selected to provide a representative sample across a large geographical area and with 13 wetlands and 2 riparian sites this was achieved. However, with some 155[1] wetlands across the study area we only collected data for, at best, 10% of the wetlands. This has implications for the abundance of birds in particular and it would be expected that a considerably higher number of birds would have been recorded across the whole of the study area. It is not expected that the number of species would have been affected greatly by the sample size since many of the same bird species were seen at all sites. This would make the Taroom wetlands quite significant at both a catchment level and a national basis. While Palm Tree and Robinson Creeks are already listed on the Directory of Important Wetlands in Australia the nature of its importance for bird species may not be fully appreciated.

Migratory species

The winter migrants of Grey Fantail, Scarlet Honeyeater and Red-capped Robin were seen as were the summer migrants of Common Koel, Channel-billed Cuckoo and Dollarbird. Of interest was the sighting of Marsh Sandpiper at Box Tree in October. This species migrates to Australia from the Arctic each summer and it indicates that at least one shorebird migratory species is using Taroom Wetlands. Other migratory species that may well use the wetlands but which were not observed are Latham's Snipe, Common Greenshank, Red-necked Stint and Sharp-tailed Sandpiper.

Many resident shorebird species were seen including Masked Lapwing, Black-winged Stilt, Red-kneed Dotterel, Black-fronted Dotterel, Red-necked Avocet and Comb-crested Jacana.

The shallow muddy edges of a wetland provide ideal feeding habitat for shorebird species and with many wetlands being shallow there was adequate habitat available.

Congregations of waterbird species which exceeded 1% of the bioregional population

The criteria for the listing of an Important Bird Area is 1% of the global population but no species met this criteria. The species which approached this criteria is;

Species	1% criteria	Highest count
Eurasian Coot	5000	4177

Given that the sample size was around 10% of all wetlands it is expected that the 1% criteria for this species would easily have been reached across the study area. Several other species would also have been close to the 1% criteria but without comprehensive data this could not be shown to be the case.

[1] Directory of Important Wetlands in Australia

Breeding

Black Swans were seen on nests at three sites, Masked Lapwings were seen with chicks, Emu were seen with chicks and several juvenile Black-fronted Dotterel were seen at Box Tree. In addition many juvenile Grey Teal and Eurasian Coot were seen. These sightings confirm that the study area is an important breeding location for waterbirds in years of good rainfall. However, the ephemeral nature of many of the wetlands would mean that only a small number would provide suitable habitat during times of drought.

Threatened species

Five threatened species were recorded (see Table 5) which indicates that the wetlands are important in providing suitable habitat for these species. The Cotton Pygmy-goose was the most widespread being seen at seven sites and the most numerous at 61 birds. This species prefers wetlands with emergent vegetation such as water lilies.

Introduced species

Two introduced species were seen which is a concern for native species since both the Common Myna and the Common Starling compete for nest hollows. Fortunately the numbers are currently quite low and the data for the spread of these species would indicate that they are recent arrivals and if a control program was initiated there would be a good chance of eradicating them.

Water quality

At most of the wetlands with the exception of Lake Murphy stock was allowed free access for watering purposes. This resulted in the trampling of edge vegetation, stirring of sediment and considerable run-off off sediment from dam banks and waterways during rain events. The result for the property owner is considerable turbidity which reduces the quality of water for stock, silting up of dams over time that reduces water levels and requires the dam to be cleaned out and the lack of fringing and emergent vegetation to oxygenate the water. The result for the environment is a significant reduction of bio-diversity in the dam as well as a general reduction in the health of the environment. Certainly many of these dams or levee banks have created valuable wetlands that provide habitat and refugia for wild life and the role of property owners in doing this work should be recognised. One method to improve this situation would be to fence wetland areas and provide off wetland watering troughs. This would improve water quality for stock, reduce maintenance as well as enhance the wetland environment and provide better habitat for the wild life that use it.

Additional species at Taroom and Glebe Weir

There is no reason why the species seen at Taroom and Glebe Weir should not be seen in the study area. It emphasises the point that surveys conducted over a large geographical area are only going to obtain a representative sample of the species that are actually present. Regular surveys over a long time frame are required to obtain comprehensive data that reveals seasonal fluctuations as well as those related to short term variations of phenomena such as ENSO.

5 Future Recommendations

The following recommendations are in no particular order or priority and implementation may well depend upon funding availability and the objectives of the funding providers.

- Continue with a further four years of annual surveys to establish a minimum of five years of base data from which trends can be inferred. At least one of these surveys should attempt a whole of study area survey to determine the total population of species and abundance across Taroom Wetlands. The additional benefit of such a survey would be to determine which species meet the 1% criteria with the possibility of Ramsar listing if such criteria could be met for several species.
- Initiate a control program for the introduced species of Common Myna and Common Starling. BirdLife Capricornia has considerable experience in the trapping of the Common Myna and would be able to provide advice and expertise if funding were available.
- Hold a community workshop to provide information about farm dam management to encourage property owners to improve the quality of water for stock, reduce sediment run off and the quality of habitat for wild life.
- Consult on a one-to-one basis with those property owners who did not give permission to access their properties to address their concerns and perhaps change their mind about giving permission. It is important for any future survey work to have access to as many wetlands across the study area as possible.
- Consider aerial surveys for large scale estimation of bird populations across the study area. An aerial survey can be very cost effective and provide data that is not available by other means. It is a very quick method of survey and would not double count birds which ground surveys over several days may tend to do.
- Provide a summary report to all property owners that gives a simple breakdown of findings. It is important that property owners receive feedback to encourage participation in the future.

6 References

Birdata is an online database that provides access to BirdLife Australia data including the Atlas of Australian Birds http://birdata.com.au/homecontent.do

Crossman, D.G. and Reimer, D.S. (1986). Mammals, birds, reptiles and amphibians of the Taroom Shire, central Queensland. Qd. J. Agric. Anim. Sci., 43:55-72

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Gilbert, J (1944) Unpublished diary of the journey of exploration of Ludwig Leichardt and party from Jimbour to Port Essington (1844-45), Mitchell Library, State Library of NSW.

Pizzey, G and Knight, F (2012) *The Field Guide to the Birds of Australia 9th Edition* Sydney, Harper Collins.

7 Appendices

Appendix 1 - List of binomial scientific bird names

Common Name	Scientific Name
Emu	*Dromaius novaehollandiae*
Brown Quail	*Coturnix ypsilophora*
Plumed Whistling-Duck	*Dendrocygna eytoni*
Wandering Whistling-Duck	*Dendrocygna arcuata*
Black Swan	*Cygnus atratus*
Australian Wood Duck	*Chenonetta jubata*
Pink-eared Duck	*Malacorhynchus membranaceus*
Cotton Pygmy-goose	*Nettapus coromandelianus*
Australasian Shoveler	*Anas rhynchotis*
Grey Teal	*Anas gracilis*
Pacific Black Duck	*Anas superciliosa*
Hardhead	*Aythya australis*
Australasian Grebe	*Tachybaptus novaehollandiae*
Great Crested Grebe	*Podiceps cristatus*
Rock Dove	*Columba livia*
Crested Pigeon	*Ocyphaps lophotes*
Squatter Pigeon	*Geophaps scripta*
Peaceful Dove	*Geopelia striata*
Bar-shouldered Dove	*Geopelia humeralis*
Australasian Darter	*Anhinga novaehollandiae*
Little Pied Cormorant	*Microcarbo melanoleucos*
Great Cormorant	*Phalacrocorax carbo*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Pied Cormorant	*Phalacrocorax varius*
Australian Pelican	*Pelecanus conspicillatus*
Black-necked Stork	*Ephippiorhynchus asiaticus*
White-necked Heron	*Ardea pacifica*
Eastern Great Egret	*Ardea modesta*
Intermediate Egret	*Ardea intermedia*
Cattle Egret	*Ardea ibis*
White-faced Heron	*Egretta novaehollandiae*
Little Egret	*Egretta garzetta*
Nankeen Night-Heron	*Nycticorax caledonicus*
Australian White Ibis	*Threskiornis molucca*
Straw-necked Ibis	*Threskiornis spinicollis*
Royal Spoonbill	*Platalea regia*
Yellow-billed Spoonbill	*Platalea flavipes*
Black-shouldered Kite	*Elanus axillaris*

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Common Name	Scientific Name
Pacific Baza	*Aviceda subcristata*
White-bellied Sea-Eagle	*Haliaeetus leucogaster*
Whistling Kite	*Haliastur sphenurus*
Black Kite	*Milvus migrans*
Collared Sparrowhawk	*Accipiter cirrocephalus*
Spotted Harrier	*Circus assimilis*
Wedge-tailed Eagle	*Aquila audax*
Nankeen Kestrel	*Falco cenchroides*
Brown Falcon	*Falco berigora*
Australian Hobby	*Falco longipennis*
Brolga	*Grus rubicunda*
Buff-banded Rail	*Gallirallus philippensis*
Spotless Crake	*Porzana tabuensis*
Dusky Moorhen	*Gallinula tenebrosa*
Eurasian Coot	*Fulica atra*
Australian Bustard	*Ardeotis australis*
Black-winged Stilt	*Himantopus himantopus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Black-fronted Dotterel	*Elseyornis melanops*
Masked Lapwing	*Vanellus miles*
Whiskered Tern	*Chlidonias hybrida*
Galah	*Eolophus roseicapillus*
Sulphur-crested Cockatoo	*Cacatua galerita*
Cockatiel	*Nymphicus hollandicus*
Rainbow Lorikeet	*Trichoglossus haematodus*
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*
Red-winged Parrot	*Aprosmictus erythropterus*
Pale-headed Rosella	*Platycercus adscitus*
Red-rumped Parrot	*Psephotus haematonotus*
Pheasant Coucal	*Centropus phasianinus*
Eastern Koel	*Eudynamys orientalis*
Channel-billed Cuckoo	*Scythrops novaehollandiae*
Pallid Cuckoo	*Cacomantis pallidus*
Fan-tailed Cuckoo	*Cacomantis flabelliformis*
Brush Cuckoo	*Cacomantis variolosus*
Barking Owl	*Ninox connivens*
Southern Boobook	*Ninox novaeseelandiae*
Laughing Kookaburra	*Dacelo novaeguineae*
Blue-winged Kookaburra	*Dacelo leachii*
Forest Kingfisher	*Todiramphus macleayii*
Sacred Kingfisher	*Todiramphus sanctus*
Rainbow Bee-eater	*Merops ornatus*

Common Name	Scientific Name
Dollarbird	*Eurystomus orientalis*
Spotted Bowerbird	*Ptilonorhynchus maculatus*
Superb Fairy-wren	*Malurus cyaneus*
Red-backed Fairy-wren	*Malurus melanocephalus*
Weebill	*Smicrornis brevirostris*
White-throated Gerygone	*Gerygone albogularis*
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*
Buff-rumped Thornbill	*Acanthiza reguloides*
Inland Thornbill	*Acanthiza apicalis*
Striated Pardalote	*Pardalotus striatus*
White-eared Honeyeater	*Lichenostomus leucotis*
White-plumed Honeyeater	*Lichenostomus penicillatus*
Noisy Miner	*Manorina melanocephala*
Yellow-throated Miner	*Manorina flavigula*
Scarlet Honeyeater	*Myzomela sanguinolenta*
Brown Honeyeater	*Lichmera indistincta*
Brown-headed Honeyeater	*Melithreptus brevirostris*
White-throated Honeyeater	*Melithreptus albogularis*
Blue-faced Honeyeater	*Entomyzon cyanotis*
Noisy Friarbird	*Philemon corniculatus*
Striped Honeyeater	*Plectorhyncha lanceolata*
Grey-crowned Babbler	*Pomatostomus temporalis*
Varied Sittella	*Daphoenositta chrysoptera*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
White-bellied Cuckoo-shrike	*Coracina papuensis*
White-winged Triller	*Lalage sueurii*
Varied Triller	*Lalage leucomela*
Rufous Whistler	*Pachycephala rufiventris*
Grey Shrike-thrush	*Colluricincla harmonica*
Australasian Figbird	*Sphecotheres vieilloti*
Olive-backed Oriole	*Oriolus sagittatus*
White-breasted Woodswallow	*Artamus leucorynchus*
Grey Butcherbird	*Cracticus torquatus*
Pied Butcherbird	*Cracticus nigrogularis*
Australian Magpie	*Cracticus tibicen*
Pied Currawong	*Strepera graculina*
Spangled Drongo	*Dicrurus bracteatus*
Grey Fantail	*Rhipidura albiscapa*
Willie Wagtail	*Rhipidura leucophrys*
Torresian Crow	*Corvus orru*
Leaden Flycatcher	*Myiagra rubecula*
Restless Flycatcher	*Myiagra inquieta*

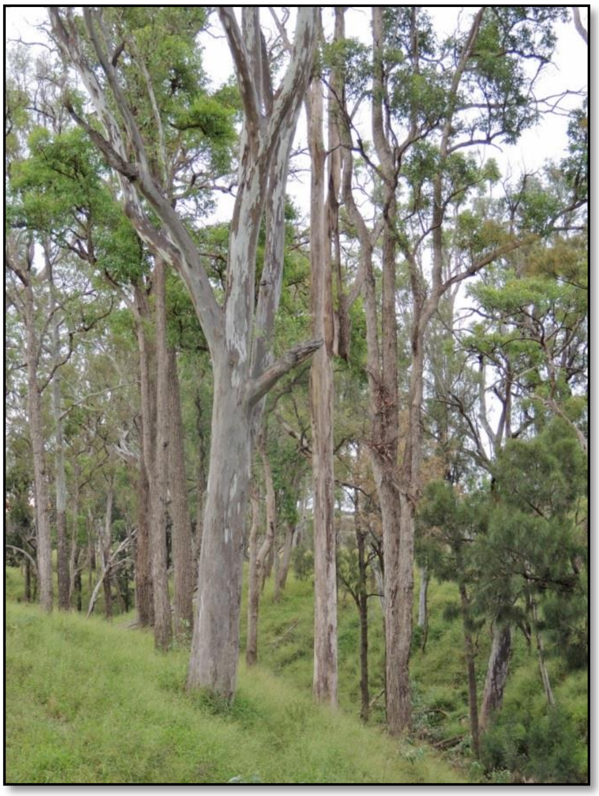
Common Name	Scientific Name
Magpie-lark	*Grallina cyanoleuca*
White-winged Chough	*Corcorax melanorhamphos*
Apostlebird	*Struthidea cinerea*
Jacky Winter	*Microeca fascinans*
Red-capped Robin	*Petroica goodenovii*
Horsfield Bushlark	*Mirafra javanica*
Golden-headed Cisticola	*Cisticola exilis*
Welcome Swallow	*Hirundo neoxena*
Fairy Martin	*Petrochelidon ariel*
Tree Martin	*Petrochelidon nigricans*
Common Starling	*Sturnus vulgaris*
Common Myna	*Sturnus tristis*
Zebra Finch	*Taeniopygia guttata*
Double-barred Finch	*Taeniopygia bichenovii*
Plum-headed Finch	*Neochmia modesta*
House Sparrow	*Passer domesticus*
Australasian Pipit	*Anthus novaeseelandiae*

Appendix 2 - Representative photographs of habitat types

The Lake – Lacustrine site, photo taken in April 2013 and full to capacity

Belle Eau lagoon – Lacustrine site, photo taken in October 2013 and drying out

Broadmere Lagoon – Palustrine site, photo taken in October 2013 and drying out



Bimbadeen riparian site, photo taken in April 2013

Appendix 3 – Species and abundance of birds recorded at each survey site

Three surveys in April, June and October 2013 were undertaken across 15 sites with a total of 142 species recorded. Full details of this data are provided in the spreadsheet data below.

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Data for April survey 2013

Family	Species	Lake Murphy	Waunui Lagoon	Bimba Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total	Species
Emu, Mound Builders and Quail	Emu									4							2		6	1
																			0	0
																			0	0
Swans, Geese, Ducks and Grebes	Pacific Black Duck	5	1				10	34		1	10		36	30	30				157	1
	Australian Grebe	26	250		1	4		2		1	60		36	23	30				433	1
	Black Swan	68	41		41		32	18			50	8	74	30	26				388	1
	Hardhead	56	12		1		5	20		10	4		70	50	20				248	1
	Chestnut Teal	156	4																160	1
	Wandering Whistling Duck									25				15					40	1
	Grey Teal	490	300		150	76	5	24			50	10	20	130	200				1455	1
	Plumed Whistling Duck							4		2				6					12	1
	Green Pygmy Geese									20									20	1
	Cotton Pygmy Geese							1	9	15		11		1					37	1
	Australasian Shoveller		14										2		7				23	1
	Great Crested Grebe	1	1		3	1	34					7	3	3					53	1
	Australian Wood Duck		6		8		5	20		20	4	7	11	50					131	1
	Freckeld duck				3									8					11	1
	Eurasian Coot	293	500		200			50		50	250	300	215	200	80				2138	1
Gannets, Cormorants Pelican	Great Cormorant					3													3	1
	Darter		1		2	3		11		2	3	4		8					34	1
	Little Pied Cormorant	1	3		2	15	3				24	1	13	3					65	1
	Pied Cormorant	22				10					3								35	1
	Little Black Cormorant	500	32		40		11	6		14		60	20	83					766	1
	Australian Pelican	350	42			4	10	350				100	9	4	5				874	1
Herons, Ibis, Spoonbills	White-faced Heron		2		2		1			2	2		3			2			14	1
	Royal Spoonbll	35	1					1					1		3				41	1
	Yellow-billed Spoonbill	3	10					3		2					3				21	1
	Little Egret	2																	2	1
	Intermediate Egret	1			1			1			1		1		4				9	1
	Great Egret	1	1		1		1					1	2	1	6				14	1
	Glossy Ibis		1		1					1					1				4	1
	Cattle Egret				20								6		24				50	1
	Straw-necked Ibis	4	25	30	2		6	4			17		5	20	1				114	1
	Australian White Ibis	1						6			2				1				10	
	White-ncked Heron		4		1		3	2			1		1	1	3				16	1
	Black-necked Stork	2	1						2					1			1		7	1

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Birds of Prey	Nankeen Kestrel										2				1	3	1		7	1
	Wedge Tailed Eagle							1					1	1		1		1	5	1
	White-bellied Sea Eagle	1				1						2	1		1				6	1
	Whistling Kite			2	1	2					1		2	1		2			11	1
	Black-shouldered Kite		1																1	1
																			0	0
	Brown Falcon						1						1			1	1		4	1
	Spotted Harrier															1			1	1
	Black Kite																1		1	1
Brolga, Crakes, Rails	Black-tailed Native Hen				6														6	1
	Brolga	2											1						3	1
	Dusky Moorhen				1					11									12	1
																			0	0
Bustard, Button Quail	Australian Bustard		4				2									2			8	1
																			0	0
																			0	0
Waders	Masked Lapwing	2	2			4		5							2				15	1
	Black-winged Stilt	95	40		40	10					1		5	18	10				219	1
	Comb-crested Jacana							2		2									4	1
	Red-kneed Dotterel					10													10	1
	Black-fronted Dotterel					6													6	1
Gulls, Terns	Whiskered Tern	7																	7	1
	Gull-billed Tern	1																	1	1
																			0	0
Pigeons, Doves	Crested Pigeon			5												4	4	4	17	1
	Peaceful Dove															2		2	4	1
	Bar-shouldered Dove																1		1	1
	Squatter Pigeon								1										1	1
	Rock Dove																		0	0
Cockatoos, Parrots,	Sulphur Crested Cockatoo			2					2							10		1	15	1
Rosella																			0	0
	Red-winged Parrot				6				2										8	1
	Cockatiel		6	7									20			4	16		53	1
	Pale Headed Rosella	2		4	2				6	2						2	6		24	1
	Rainbow Lorikeet			2					12										14	1
	Galah				3		4		2				35			2	6		52	1

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Cuckoos																			0	0
	Pheasant coucal			1	1				2										4	1
																			0	0
Swifts, Kingfishers	Laughing Kookaburra			1					1		1					1			4	1
	Sacred Kingfisher						1												1	1
	Blue-winged kookaburra															1			1	1
	Rainbow Bee-eater															4			4	1
	Dollarbird																1		1	1
	Forest Kingfisher					1													1	1
																			0	0
																			0	0
Wrens, Pardalotes	Red-backed Fairy Wren		4		3					4					4	3			18	1
Gerygone	White-throated Gerygone													1					1	1
	Inland Thornbill													2					2	1
																			0	0
Scrubwrens, Allies	Striated Pardalote	1					4		1		1							4	11	1
	Weebill					4								6				1	11	1
																			0	0
Honeyeaters	Blue-faced Honeyeater			2			2		2										6	1
	Little Friarbird					10													10	1
	White-throated Honeyeater					2						4						6	12	1
	Striped Honeyeater							1											1	1
	Noisy Friarbird								1										1	1
																			0	0
	Noisy Miner	2		20	5	6		2			10			10					55	1
	Noisy Friarbird										2		4						6	1
	White-plumed Honeyeater																		0	0
Chats, Robins	Jackie Winter												1					2	3	1
																			0	0
																			0	0
Babblers, Whipbird	Grey-crowned Babbler	3							4					12			3		22	1
																			0	0
																			0	0
																			0	0

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Whistlers,	Rufous Whistler					2								2					4	1
Shrike Thrush																			0	0
																			0	0
Magpie Lark,	Grey Fantail													2				1	3	1
Flycatchers, Fantail	Restless Flycatcher	1					1	1								2			5	1
	Magpie Lark				10	2			1				2		2	1			18	1
																			0	0
Cuckoo Shrike, Oriole	Black-faced Cuckoo Shrike		2				1				2						2		7	1
Figbird	White-bellied Cuckoo Shrike													2					2	1
																			0	0
Woodswallows	White-breasted Woodswallow	1	2					2								1			6	1
																			0	0
																			0	0
Magpie, Butcherbirds	Grey Butcherbird	1			2		1		1					1					6	1
Birds of Paradise	Australian Magpie			2			3		3							4	1		13	1
	Pied Burtcherbird		1	2							1		2			1	5		12	1
	Pied Currawong					1			1										2	1
	Torresian Crow	1	10	40					2							2	10		65	1
Ravens, Mudnesters	White-winged Chough					6													6	1
																			0	0
																			0	0
Bowerbirds, Larks,	Willie Wagtail	1				3		2								1	2	1	10	1
Pipits & Wagtails	Apostlebird								8							16	12		36	1
	Australasian Pipit														2				2	1
	Horsfield's Bushlark														2				2	1
																			0	0
Sparrows, Finches	Plum-headed Finch															6		3	9	1
	Double-barred Finch															20			20	1
																			0	0
																			0	0
Swallows, Bulbuls	Tree Martin							2					20			6			28	1
Martins, Silvereye																			0	0
																			0	0
Myna, Starling	Common Myna														6				6	1

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Summary of data for April survey 2013	Lake Murphy	Waunui Lagoon	Bimbadeen Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total birds	Total species
Total number of birds	2138	1324	120	559	186	146	27	20	188	502	515	623	725	474	105	75	26	8344	104
Total number of species	35	32	14	30	24	23	27	20	19	24	13	32	32	26	28	18	11		

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Data for June survey 2013

Family	Species	Lake Murphy	Waunui Lagoon	Bimba Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total	Species
Emu, Mound Builders and Quail	Emu							2					2			4	3		11	1
	Brown Quail	1																	1	1
																			0	0
Swans, Geese, Ducks and Grebes	Pacific Black Duck				10		2	81		25	26		20						164	1
	Australian Grebe	330	135		34	2	200	40		30	41	21	60	141					1034	1
	Black Swan	94	26		6		20	8			15	34	20	3					226	1
	Hardhead	330			5		4	22		18	10	3	5	72					469	1
																			0	0
																			0	0
	Grey Teal	550	220		21	8		18		1	95	26	92	52					1083	1
																			0	0
																			0	0
	Cotton Pygmy Geese				2						5	4	4						15	1
	Australasian Shoveller	8	6				4			3	4		4						29	1
	Great Crested Grebe						5					2		2					9	1
	Australian Wood Duck	19					2	8			51	15	6	97			12		210	1
	Freckeld duck				3									20					23	1
	Pink-eared Duck				4	20													24	1
	Magpie Goose												1						1	1
	Eurasian Coot	1410	210				270	75		95	55	380	182	1500					4177	1
Gannets, Cormorants Pelican	Great Cormorant													20					20	1
																			0	0
	Darter	2			6	1	6	8		2	2	6	5	4					42	1
	Little Pied Cormorant	1			8		6	32		2		5	6	20					80	1
																			0	0
	Pied Cormorant									4									4	1
	Little Black Cormorant	80			10	1	6	100		200	208	10	20	17					652	1
	Australian Pelican	13	42		12	14	49	26		3		62	8	3		2			234	1

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Herons, Ibis, Spoonbills	White-faced Heron	1	6					2		1	2		5				1		18	1
	Royal Spoonbll	69			18			11		8	2	21	6	1					136	1
	Yellow-billed Spoonbill	9	10		2			9		9	2	3	12	9					65	1
																			0	0
	Intermediate Egret				1		6			1									8	1
	Great Egret	1	1		2		2	3		1	1		2	2					15	1
																			0	0
	Cattle Egret				46		12						3						61	1
	Straw-necked Ibis	1	21			2	1	5			5		8	6		2	3		54	1
	Australian White Ibis						8	1			1	2							12	1
	White-necked Heron	7	8	3			1	4					2	2		1	2		30	1
																			0	0
Birds of Prey	Nankeen Kestrel		1	1	1	1										1		1	6	1
	Wedge Tailed Eagle			1									1				5		7	1
	White-bellied Sea Eagle	1												2					3	1
	Whistling Kite	8		1			2	1		1						1	2	1	17	1
	Black-shouldered Kite															2			2	1
	Osprey	2																	2	1
	Brown Falcon		1								1								2	1
	Spotted Harrier			1															1	1
	Pacific Baza		1	1															2	1
																			0	0
Brolga, Crakes, Rails																			0	0
	Brolga													2				2	4	1
	Dusky Moorhen	2					1												3	1
	Purple Swamphen												1						1	1
Bustard, Button Quail	Australian Bustard															2			2	1
																			0	0
																			0	0
Waders	Masked Lapwing	25	5		2	2	2	2		2		4	10				2		56	1
	Black-winged Stilt	30	25		20	6		4			2		4	14					105	1
	Comb-crested Jacana							1		5				10					16	1
	Red-kneed Dotterel					4			2										6	1
																			0	0
	Black-fronted Dotterel				2	2							1						5	1

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Gulls, Terns																			0	0
																			0	0
																			0	0
																			0	0
																			0	0
Pigeons, Doves	Crested Pigeon	2		1													6	10	19	1
	Peaceful Dove																10		10	1
	Bar-shouldered Dove																4		4	1
																			0	0
																			0	0
Cockatoos, Parrots,	Sulphur Crested Cockatoo				2									1					3	1
Rosella	Budgerigar																10		10	1
	Red-winged Parrot								2		2						4	3	11	1
	Cockatiel												3						3	1
	Pale Headed Rosella	2		3	2	2			6								4	4	23	1
	Rainbow Lorikeet	2		5			2		6		4			6				5	30	1
	Scaly-breasted Lorikeet	4							2										6	1
	Galah	30			50		2											10	92	1
Cuckoos																			0	0
	Pheasant coucal									1									1	1
																			0	0
																			0	0
Night Birds																			0	0
																			0	0
																			0	0
																			0	0
Swifts, Kingfishers	Laughing Kookaburra			1		2	1	2								2	1	2	11	1
																			0	0
	Blue-winged kookaburra							4								1			5	1
Wrens, Pardalotes	Superb Fairy-wren																		0	0
Gerygone	Red-backed Fairy Wren	4									2					6		6	18	1
	White-throated Gerygone											1						1	2	1
																			0	0
	Yellow Thornbill																	4	4	1
	Varied Sitella																	8	8	1

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Scrubwrens, Allies	Striated Pardalote	1						5	4			1					1	2	14	1
	Weebill					2		5										4	11	1
																			0	0
Honeyeaters	Blue-faced Honeyeater	3							2		2							3	10	1
																			0	0
	White-throated Honeyeater					4											2	2	8	1
	Striped Honeyeater												2				1		3	1
																			0	0
																			0	0
	Noisy Miner	10		20					4							5	4	4	47	1
																			0	0
																			0	0
Chats, Robins	Jackie Winter																2		2	1
	Red-capped Robin																2	2	4	1
																			0	0
																			0	0
Babblers, Whipbird	Grey-crowned Babbler							6					4			4		6	20	1
																			0	0
																			0	0
Quail Thrush & Allies																			0	0
																			0	0
																			0	0
	Rufous Whistler					2		1						3				1	7	1
Whistlers,	Grey-shrike Thrush																1		1	1
Shrike Thrush																			0	0
																			0	0
																			0	0
Magpie Lark,	Grey Fantail					3					2			4				2	11	1
Flycatchers, Fantail	Restless Flycatcher	1																1	2	1
	Magpie Lark	10		4	2	2	2	17	2			2	10	6		2			59	1
																			0	0
Cuckoo Shrike, Oriole																			0	0
Figbird	Black-faced Cuckoo Shrike					1										1			2	1

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Magpie, Butcherbirds Birds of Paradise	Grey Butcherbird			1			2			1				1		1		1	7	1
	Australian Magpie	2		3					2			2				6		4	19	1
	Pied Burtcherbird						1		1				1			2	1	2	8	1
	Pied Currawong																2		2	1
	Torresian Crow			1					4	2						8	5		20	1
Ravens, Mudnesters	White-winged Chough													12			6	10	28	1
																			0	0
																			0	0
																			0	0
Bowerbirds, Larks, Pipits & Wagtails	Willie Wagtail	2		3				1					2	2					10	1
	Apostlebird												40			6	40		86	1
																4			4	1
																			0	0
																			0	0
																			0	0
Sparrows, Finches	Plum-headed Finch																	10	10	1
	Double-barred Finch																2	2	4	1
	House Sparrow																		0	0
																			0	0
Sunbird, Mistletoe Bird																			0	0
																			0	0
																			0	0
																			0	0
Swallows, Bulbuls Martins, Silvereye	Welcome Swallow				6									50					56	1
																			0	0
	Tree Martin	10					6			10									26	1

Summary of data for June survey 2013	Lake Murphy	Waunui Lagoon	Bimbadeen Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Incid to Broadmere	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total birds	Total Species
Total number of birds	3077	718	50	277	81	625	31	12	425	540	604	552	2084	0	63	138	113	9888	94
Total number of species	38	16	16	26	20	28	31	12	23	24	20	34	31	0	21	28	29		

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Data for October survey 2013

Family	Species	Lake Murphy	Waunui Lagoon	Bimba Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Robinson Creek	Glenhaughton Road Incid	Ghinghinda Rd Incid	Flagstaff Rd Incid	Total	Species
Emu, Mound Builders and Quail	Emu	22		4	4				7									6	3	46	1
	Brown Quail																			0	0
																				0	0
Swans, Geese, Ducks and Grebes	Pacific Black Duck				2	12	2	8			30		1	4	20	2				81	1
	Australian Grebe	131				12	91	54		25	4	61	12	3		39				432	1
	Black Swan		1				81	7		30	3	54	16	4	53	4				253	1
	Hardhead	10				2	11			6	30					2				61	1
	Chestnut Teal																			0	0
	Wandering Whistling Duck											1								1	1
	Grey Teal	640			152	320	23	57		80	300	57	193	40	600	13				2475	1
	Plumed Whistling Duck																			0	0
	Green Pygmy Geese																			0	0
	Cotton Pygmy Geese							5		12		17								34	1
	Australasian Shoveller	13					1													14	1
	Great Crested Grebe						1													1	1
	Australian Wood Duck	55			8		35			25		10	17	60	100	85				395	1
	Freckled duck																			0	0
	Pink-eared Duck					41														41	1
	Magpie Goose																			0	0
	Eurasian Coot						430	50		80		360								920	1
Gannets, Cormorants Pelican	Great Cormorant																			0	0
																				0	0
	Darter	1				1	1	4				3		3						13	1
	Little Pied Cormorant						4	1				6		5	2					18	1
																				0	0
	Pied Cormorant																			0	0
	Little Black Cormorant	30					1	1		6			1	100		10				149	1
	Australian Pelican	35			12	1	12	3					3	5	20					91	1

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Herons, Ibis, Spoonbills	White-faced Heron	5	10	1	3		1	2	1	1	1				1			1		27	1
	Royal Spoonbll				8								6							14	1
	Yellow-billed Spoonbill	14			16	1		1		1			8		6					47	1
	Little Egret																			0	0
	Intermediate Egret				2		1			2	2									7	1
	Great Egret				1	1	1	1		2	2		2		4	1				15	1
	Glossy Ibis				2		1	1			3				2					9	1
	Cattle Egret				15										25			10		50	1
	Straw-necked Ibis				16					2					1			7		26	1
	Australian White Ibis	1													1					2	1
	White-necked Heron	4		1			1			1	1	1		1	4					14	1
	Nankeen Night-heron																			0	0
	Black-necked Stork	1										1								2	1
Birds of Prey	Nankeen Kestrel						1	1		1					1					4	1
	Wedge Tailed Eagle								1						1			2		4	1
	White-bellied Sea Eagle	1													1	1				3	1
	Whistling Kite	2		1											1	1		1	1	7	1
																				0	0
																				0	0
	Brown Falcon																	1		1	1
																				0	0
	Collared Sparrowhwk																		2	2	1
																				0	0
Brolga, Crakes, Rails																				0	0
	Brolga									2			2	3	2			2		11	1
																				0	0
																				0	0
	Spotless Crake														1					1	1
																				0	0
Bustard, Button Quail	Australian Bustard															1				1	1
																				0	0
																				0	0
Waders	Masked Lapwing	33	13	8		4	3	4	2		11	5	4	10	42			6		145	1
	Black-winged Stilt	135	75		40	28	32	17	4	6	50	24	10	34	84					539	1
	Comb-crested Jacana							2		7										9	1
	Red-kneed Dotterel							1								2				3	1
	Red-necked Avocet	140																		140	1
	Australian Pratincole		1																	1	1
	Marsh Sandpiper														2					2	1
	Black-fronted Dotterel					2		1							30	1				34	1

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Gulls, Terns	Whiskered Tern	6												5	3					14	1
	Gull-billed Tern																			0	0
	Caspian Tern						2													2	1
																				0	0
Pigeons, Doves	Crested Pigeon								1						1		1	3		6	1
	Peaceful Dove													1		2		2	2	7	1
	Bar-shouldered Dove																			0	0
	Squatter Pigeon											2								2	1
																				0	0
Cockatoos, Parrots, Rosella	Sulphur Crested Cockatoo	1								1		1	2					5	2	12	1
	Budgerigar															50				50	1
	Red-winged Parrot									1										1	1
	Cockatiel															6				6	1
	Pale Headed Rosella	2			4				2	1								2		11	1
	Rainbow Lorikeet	2	6			2						3						10	6	29	1
	Scaly-breasted Lorikeet											3							3	6	1
	Turquoise Parrot															2				2	1
	Red-rumped Parrot															3				3	1
	Galah							2		1		1				2		6		12	1
Cuckoos	Brush Cuckoo															1				1	1
																				0	0
																				0	0
	Channel-bill Cuckoo											1								1	1
Swifts, Kingfishers	Laughing Kookaburra	1		1		1	1		2			2	1		1			1		11	1
	Sacred Kingfisher	1					1	1											2	5	1
	Blue-winged kookaburra							3												3	1
	Rainbow Bee-eater																	2		2	1
	Dollarbird			1			1		1	1		1							2	7	1
																				0	0
Wrens, Pardalotes Gerygone																				0	0
	White-throated Gerygone						7			1									6	14	1
	Yellow-rumped Thornbill															6			2	8	1
	Buff-rumped Thornbill		1																	1	1

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Scrubwrens, Allies	Striated Pardalote											1						1	1	3	1
	Weebill					3														3	1
																				0	0
Honeyeaters	Blue-faced Honeyeater	2							2				1						1	6	1
	Little Friarbird					2														2	1
	White-throated Honeyeater						3													3	1
	Striped Honeyeater															1			1	2	1
	Noisy Friarbird			5	2	3	1									2		1	2	16	1
	Yellow -throated Miner																			0	0
	Noisy Miner	10		6				2	5			10						4		37	1
	White-eared Honeyeater					1														1	1
	Brown Honeyeater															1				1	1
	White-plumed Honeyeater																		1	1	1
																				0	0
Chats, Robins	Jackie Winter						3												4	7	1
																				0	0
																				0	0
Babblers, Whipbird	Grey-crowned Babbler	6						6	5					5		4		4		30	1
																				0	0
	Rufous Whistler						1											1	2	4	1
Whistlers, Shrike Thrush	Grey-shrike Thrush																	1	1	2	1
	White-winged Triller						2													2	1
																				0	0
Magpie Lark, Flycatchers, Fantail																				0	0
	Restless Flycatcher						1												2	3	1
	Magpie Lark	2	8				6	2	2	2	2				4	2				30	1
	Leaden Flycatcher						1													1	1
Cuckoo Shrike, Oriole Figbird	Figbird	2																		2	1
	Black-faced Cuckoo Shrike	1						1										1	1	4	1
	White-bellied Cuckoo Shrike																		1	1	1
	Olive-backed Oriole								1											1	1
Woodswallows	White-breasted Woodswal	6													1	4				11	1
																				0	0

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Group	Species	Lake Murphy	Waunui Lagoon	Bimba Riparian	Broadmere Lagoon	Belle Eau Lagoon	Lakefield Lagoon	Jamberoo Lagoon	Gwamb Riparian	Lakefield Lake	Gwamb White Wine Lagoon	Gwamb Red Wine Lagoon	Wythburn Lagoon	The Lake	Box Tree Lagoon	Robinson Creek	Glenhaughton Road Incid	Ghinghinda Rd Incid	Flagstaff Rd Incid	Number of birds	Species
Magpie, Butcherbirds Birds of Paradise	Grey Butcherbird	1			1			1		1	1		1						1	7	1
	Australian Magpie	2				1	2		2				1		2			2		12	1
	Pied Butcherbird	1					1		1	1			5					1	1	11	1
	Pied Currawong								1					2				1		4	1
	Torresian Crow	6	2	2		1	4		2								4	4	2	27	1
Ravens, Mudnesters	White-winged Chough																		7	7	1
																				0	0
																				0	0
																				0	0
Bowerbirds, Larks, Pipits & Wagtails	Willie Wagtail	1	2	1	2		2	1					1		1	2	2		1	16	1
	Apostlebird						5		6			5				6		15		37	1
																		1		1	1
																				0	0
	Spotted Bowerbird								1											1	1
																				0	0
Sparrows, Finches																				0	0
	Double-barred Finch					7										12				19	1
																				0	0
Swallows, Bulbuls Martins, Silvereye	Welcome Swallow	2											10		1					13	1
																				0	0
	Tree Martin									4						4				8	1
																				0	0
Warblers, Thrushes	Golden-headed Cisticola														4					4	1
																				0	0
																				0	0
	European Starling			3																3	1
Myna, Starling	Common Myna			1											2					3	1
	Total number of birds	1328	119	35	290	446	778	240	49	303	440	630	297	285	1024	272	7	104	60	6707	110
	Total number of species	38	10	13	18	21	39	29	20	28	14	24	21	17	34	31	3	30	27		

Summary of data for October survey 2013

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FITZROY BASIN ASSOCIATION

Aquatic Ecology Report

FITZROY BASIN ASSOCIATION

Our country, Our future

Aquatic Ecology Report - Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by Alluvium Consulting Australia for Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

Aquatic Ecology - Palm Tree & Robinson Creek Wetlands

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This report was prepared on behalf of FBA by Alluvium Consulting Australia.

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Summary

The Palm Tree and Robinson Creeks Wetland system is listed under the Directory of Important Wetlands of Australia (DIWA). The DIWA site bounds an area of 50 223ha located approximately 28km north of Taroom in the upper Dawson Catchment (Figure 1). The wetland system is characterised by a series of shallow, mostly seasonal swamps, lakes and streams, and to date has received very little formal study (DSEWPaC 2010). Lake Murphy, at the lower reaches of Robinson Creek, is a listed protected area (Lake Murphy Conservation Park) under Queensland legislation. Larger wetlands such as Lake Murphy are considered semi-permanent and may only reach near-dry condition following periods of drought.

The current study is part of a larger program of work being undertaken by the Fitzroy Basin Association (FBA) to enhance our social and ecological understanding of the Palm Tree Creek and Robinson Creek Wetlands.

Alluvium Consulting Australia Pty Ltd (Alluvium) was commissioned on behalf of FBA to undertake assessments of hydrology, aquatic fauna and local perceptions of the natural history of the Palm Tree Creek and Robinson Creek Wetlands, with the following specific objectives:

1. Complete hydrological assessments to produce a conceptual model of ground and surface water, processes, linkages, transport and storage in the landscape
2. Complete aquatic fauna assessments to identify aquatic habitat and fauna, including distribution, diversity and abundance of macro-invertebrates, turtles and fish, and identification of ecologically significant wetlands
3. Complete a social science study on local landholders' perspectives of the wetlands, to document change and trends reported by those who have lived in the area for generations.

Three components of work were undertaken:

- A desktop study of surface water hydrology was conducted by Alluvium using historical rainfall and stream gauge data, satellite imagery, 2D hydrological modelling and local knowledge. Direct information on groundwater was very poor, enabling only limited inferences on the contributions of groundwater to the wetlands.
- Eight palustrine wetlands in the system were surveyed by frc environmental for aquatic fauna in April 2013.
- The natural history study captured a range of natural history observations, local uses and stories of the wetlands from thirteen landholders, whose families have lived and worked by these wetlands for generations. These locals were engaged to share their stories, personal recollections and photo collections during seven separate interviews conducted in March and April 2013.

This brief synopsis of the ecology of the Palm Tree Creek and Robinson Creek Wetlands uses key information from each of the above studies to help provide a preliminary understanding of the ecosystem components and processes, ecosystem services and values of the Palm Tree Creek and Robinson Creek wetlands and catchment system. The preliminary nature of this study will also identify knowledge gaps relevant to improving our understanding, management and maintenance of the site. This report is intended to assist those with interest in wise use and appropriate management of the wetlands, and in detection of changes to its ecosystem services and values, to:

- communicate the key ecological processes and values of these wetlands to wider audiences, and
- develop management and action plans for maintaining or improving the condition, ecosystem services and community values of the wetlands.

Landscape and Geomorphology

The headwaters of these two sub-catchments arise in the eucalypt woodlands and forests of Expedition National Park and Palm Grove National Park. The upper-middle portions of the catchments are partially cleared for grazing. Mid and lower portions of the two catchments are more extensively cleared.

Much of the catchment area is on a sandstone, siltstone & mudstone surface geology. However the Palm Tree Creek sub-catchment is on a more sandy geology and the Robinson Creek wetlands occur on more localised deposits of clay, silt, sand and colluvials. It may be the specific geomorphology that contributes to this regionally unique abundance of water pooling and wetland features "off-stream" of the main creeks, but further fluvial geomorphology studies would help address this knowledge gap.

Hydrology

The DIWA site is a complex of approximately 154 wetlands comprising mostly palustrine (swamp) and at least one semi-permanent lacustrine (lake) habitat (Figure 4). Almost all of these wetlands are located on the floodplain, immediately connected and adjacent to the main streams, but also have their own local source catchments. Although streams are also classed as wetlands, the abundant floodplain palustrine and lacustrine wetlands are the focus of the DIWA site and thus the key subject of this study.

The majority of floodplain wetlands in this system are shallow (up to 2m depth), except for particularly wet years. Most small to medium sized wetlands are dry, or nearly dry, for several months each year and may remain continuously dry for several years during drought. Lake Murphy (a gazetted Conservation Park), at 290ha and still surrounded with remnant terrestrial vegetation, is considered a semi-permanent lake.

Palm Tree Creek sub-catchment supports at least 134 wetlands, including approximately 50 wetlands at least 8ha in size (five of these are between 50ha and 70ha in size). The Robinson Creek sub-catchment only supports around 20 individual wetlands, but 7 of these are relatively large (ranging between 50ha and 290ha) in area.

Wetland area responds to changes in rainfall, and usually displays maximum extents during summer monsoon months (November to March), but can continue into autumn (up to April) under prolonged wet seasons. Peaks in wetland extent have occurred in winter months in recent years which have been much wetter than average (e.g., 2011, Figure 5).

Whilst Queensland Government wetland mapping data indicates a total 2,527ha of non-riverine (lacustrine and palustrine) wetland, the total extent of inundated (wet) area in the DIWA site (calculated from Landsat imagery) in an average wet season can be approximately 4,000ha (Alluvium 2014). Extreme wet events may result in approximately 9,000ha of inundated habitat (after flood waters recede). Much of these inundated areas following prolonged rainfall events may include riparian or floodplain habitat above the level of wetland extent. Based on analyses of Landsat images, late dry season extent of inundated area may decline to around 1000ha across the site during "average" rainfall years (Figure 5). During severe drought, total wet areas may only range between a few tens of hectares to 150 ha (Alluvium 2013b).

2D modelling at selected wetlands estimated that approximately 50% of wetlands (primarily in the lower catchments) receive overflows from stream channels as frequently as 1-year ARI events (Alluvium 2013b). Models also estimate that approximately 70% of wetlands receive riverine inflows under 10-year ARI events. Both these results are in general supported by local landholder observations. Wetlands in the upper catchments, particularly above the flat alluvial plains, may receive less frequent riverine inflows. Water balance assessments indicate that local run-off sources may be relatively important to most wetlands, particularly those in the upper catchments.

Water Quality

Water quality sampling from 8 wetlands in April 2013 (for water temperature, conductivity, pH, turbidity and dissolved oxygen) provided only preliminary insights into the water quality conditions in relation to environmental values. The observations below should be used with caution until water quality can be assessed across more sites and over seasonal and inter-annual periods.

Although reasonable populations of native aquatic life were found in most wetlands, some water quality parameters were outside the acceptable ranges of Water Quality Objectives for the upper Dawson catchment. Turbidity levels exceeding Water Quality Objectives (WQO) in some wetlands were associated with high disturbance from cattle, and low pH and dissolved oxygen levels in some wetlands possibly result from high loads of organic matter and biological oxygen demand. Water clarity in the wetlands was similar to, or in places greater than, the water clarity recorded in the Dawson River, and was best in wetlands with well-established native wetland plants. However high sediment loads and temporarily high water turbidity levels can follow large rainfall events and flooding.

Wetland Flora

These palustrine and lacustrine wetlands predominantly support (in decreasing order) the wetland regional ecosystems 11.3.27g, 11.3.27d, 11.3.27c and 11.3.27 (DEHP 2013c). These vegetation communities mostly overlap the wetland maps and include open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. They are widespread throughout the Brigalow Belt bioregion and their biodiversity conservation status is classified "Of Concern".

Most wetlands are open shallow water with areas of submerged or floating aquatic vegetation, plus stands of native emergent wetland plants (sedges) along some margins or as isolated patches, and shoreline bands of wetland grasses and annual forb thickets (see Section 3.3). The autumn 2013 flora surveys of 50 wetlands identified 8 groups or community types of wetland flora, mostly comprising a good diversity of wetland grasses, herbs and forbes, sedges and rushes, water lilies, nardoo and vallisneria (Halford, Drimer & Fensham In Prep). They often occurred in bands or zones of vegetation occupying different levels below the edge of terrestrial vegetation. While located within a landscape with long grazing history, the extent of introduced flora was surprisingly low at wetlands across the DIWA site (Halford, Drimer & Fensham In Prep).

Most wetlands still retain belts or woodlands of large trees around the perimeter of their riparian zone, although these appear to be declining in some agricultural areas and around large wetlands. Some locals have observed over several decades that sedimentation appears to be causing some large wetlands to become shallower and larger. This process may likely contribute to more frequent inundation/waterlogging and then death of terrestrial vegetation.

Ecosystem Services and Values

The palustrine and lacustrine wetlands of the Palm Tree Creek and Robinson Creek DIWA site provide several ecosystem services and values locally and within the Brigalow Belt South bioregion and the Fitzroy River Drainage Basin (See section 3.4.1). Some of these noted within this study include:

Regionally unique wetland complex: The Palm Tree Creek and Robinson Creek wetlands DIWA site provides a large aggregation of natural, semi-permanent, freshwater swamps and lakes concentrated in a single sub-catchment of the upper Dawson River catchment. The concentrated aggregation, geomorphology, hydrology and biological characteristics of these wetlands creates a localised wetland system that is not well represented on this scale elsewhere in the Fitzroy River Drainage Basin and the Brigalow Belt South bioregion.

Diverse and abundant native wetland flora: Most of the surveyed wetlands contain mostly open shallow water with areas of submerged or floating aquatic vegetation, plus stands of native emergent wetland plants (sedges, reeds) along some margins or as isolated patches, and shoreline bands of wetland grasses and annual forb thickets. The number and extent of serious invasive weeds are relatively low for wetlands that have had over 100 years of grazing use.

The wetland regional ecosystems 11.3.27g, 11.3.27d, 11.3.27c and 11.3.27 represented here include open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. They are widespread throughout the Brigalow Belt South bioregion and their biodiversity conservation status is classified "Of Concern".

The abundance and diversity of native wetland plants in the wetland riparian zones and submerged areas helps to filter sediments and nutrients before they enter river systems. They also provide abundant good quality habitat and food for aquatic macroinvertebrates, fish, turtles and waterbirds.

Habitat for aquatic fauna: These swamps and lakes have an important role at both local and regional scales in providing habitat and rich food webs suitable for sustaining populations of several native aquatic macroinvertebrates, fish and reptiles (frc environmental 2013). Wetlands were of particularly high ecological value to aquatic fauna if they provided both shallow and deep pools, large wood snags (e.g. fallen trees), plus a diverse range of submerged, emergent and floating aquatic plants (frc environmental 2013). Overall, surveys indicate that the regional ecological value of the DIWA site wetlands in terms of aquatic fauna and is moderate to high (frc environmental 2013, Briggs 2013). Waterbirds are a conspicuous part of the site's wetland fauna (Briggs 2013), and reflect the overall condition of wetlands in terms of food availability, support to breeding, as habitat roosting and for migratory species. Local observations and previous studies (e.g., Kelly 2011) concur that these wetlands have long supported a good diversity and abundance of wetland birds as well as non-wetland birds.

Habitat for threatened species: The site supports one non-wetland bird species (squatter pigeon) declared as nationally vulnerable. The squatter pigeon, turquoise parrot and three waterbirds (cotton pygmy-goose, black-necked stork, freckled duck) are declared as threatened in Queensland (Briggs 2013). The nationally threatened koala is also found within the DIWA site (Fauna Track 2013).

Refuge habitat: At times, when other regions are in drought, this large wetland complex may provide critical refuge for populations of many wetland species (particularly birds, fish, amphibians or freshwater turtles) occurring across inland Queensland. Some migratory species may also depend on these wetlands for feeding and resting during parts of their life cycle.

Water resource for stock: Cattle grazing on pastoral leases has been the dominant land use and economy derived within the DIWA site for more than 100 years, and the natural wetlands have always been used as a water resource and feeding area for stock.

Recreation and amenity: The wetlands provide attractive water-scapes and cool recreational areas for people during hot summer months. Investigations into the cultural heritage values of these wetlands to traditional indigenous landholders should provide useful additions to understanding the site's overall importance in the region.

Some of the above values contribute to how the Palm Tree Creek and Robinson Creek wetlands DIWA site meets criteria for listing as a nationally (and potentially internationally) important site:

DIWA Criteria 1: It is a good example of a wetland type occurring within a biogeographic region in Australia.

DIWA Criteria 5: The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.

The site is considered to meet Ramsar Criteria 1 on uniqueness, and potentially meets Criteria 4, 5 and 6 for listing under the Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat, Ramsar 1971). Note that although a wetland site may be considered to meet criteria for listing as a wetland of international significance, the site can only be recognised as a Ramsar site if a formal nomination is submitted and successful for the site's inclusion on the Ramsar List of Wetlands of International Importance. At least the following criteria may be considered for this site.

Ramsar Criteria 1: "*A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region*".

Additional investigations are recommended to improve the evidence on whether the DIWA site meets Ramsar criteria 4, 5 and 6:

Ramsar Criteria 4: : "*A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*".

Ramsar Criteria 5: "*A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds*".

Ramsar Criteria 6: "*A wetland should be considered internationally important if it regularly supports 1% of the individuals of the population of one species or sub-species of waterbird*".

Threats and Impacts

Drivers of "natural" change in the wetlands include natural climatic, geomorphological, hydrological and biological processes, but human land-use and changes in overall climate patterns create abnormal pressures on the ecological integrity and critical functions of wetlands. The following threats are discussed in further detail within the report. Recommendations on addressing these threats are also listed further below.

Erosion and Sedimentation: The local soils are naturally highly erosive, but grazing, reductions in vegetation cover, and modifications to drainage channels are among several possible causes of increased landscape erosion and sediment in-filling of the wetlands.

Cattle grazing : High levels of disturbance to sediments, increased turbidity and loss of wetland plants through cattle trampling and feeding.

Feral animals: Digging and feeding by feral pigs causes habitat damage and removal of wetland plants, re-suspension of sediments and increased turbidity, introduction of disease and parasites, and adverse impacts on wetland aquatic fauna. Feral cat, fox and wild dog populations have been increasing here and across much of inland Queensland, posing increasing threats to populations of native skinks, birds and mammals (Fauna Track 2013).

Barriers to connectivity: Downstream of the study area, several weirs and dams create impediments to migratory movements of many aquatic species. These impacts are most strongly evident in the observed declines in populations of large eels in these wetlands over several decades. Addressing this threat (e.g. through use of fish passage facilities on existing barriers and avoiding construction of additional barriers) will benefit the overall biodiversity values of these wetlands and other parts of the upper Dawson catchment.

Introduced aquatic fauna: Existing populations of the introduced mosquito fish *Gambusia holbrooki* appear to be small, but if expanded to greater proportions would present threats to native species through competition for food and habitat.

Full Storage Level (FSL) of the proposed Nathan Dam will reach upstream to the Leichhardt Highway, immediately below the Palm Tree Creek and Robinson Creek Wetlands. Any exotic fish species introduced at such a dam would likely further colonise the Palm Tree Creek and Robinson Creek wetlands, and potentially impact on populations of native species.

Invasive plants: Invasions of cats claw vine (*Macfadyena unguis-cati*), which appear to have started recently at upstream sites, are now present along some main streams. The serious environmental and pasture weed lippia (*Phyla canescens)* which has existed in the catchment for several decades, is still limited in extent, but may move into a rapid expansion phase under climate or irrigation regimes that produce regular watering. These invasions should be monitored and addressed as early as possible before their control becomes more costly and less effective.

Introduced grasses, particularly buffel grass, have been planted on several properties in recent decades. Nevertheless, it appears that native grasses and woodland species are in relatively good condition, as several refuge areas of remnant habitat still exist over much of the landscape.

Climate Change: Changes to climate patterns may lead to a range of other changes in the system, e.g.:

- Extremes in flood and drought events
- Changes in vegetation
- More extreme fires
- More extreme hydrological forces associated with flooding events
- Increased erosive scouring of landscape and streams, causing sedimentation and shallowing in wetlands

Adapting to these potential drivers and changes will require efforts to improve soil, water and vegetation across the landscape – the same components that underpin the landscape's capacity to support agriculture. Adaptations and changes in land use, to be most effective, may require coordinated efforts across the whole catchment.

Recommendations

Management planning and education programs to maintain ecological character of the Palm Tree Creek and Robinson Creek wetlands would benefit from addressing the following knowledge gaps:

1. Further investigations into alluvial and artesian groundwater resources and hydrology to understand their potential influence on springs, wetlands and streams in this catchment.
2. An adequate understanding of the causes and mechanisms of sediment accretion in wetlands requires more targeted fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the landscape.
3. Investigations into indigenous knowledge and cultural heritage at the site may improve understanding of the sites' cultural values and contribute additional management options.
4. Addressing the knowledge gaps on particular ecosystem components and processes will enable more locally specific conceptual models to be developed and used for targeted management and education purposes.
5. More detailed studies are needed firstly to establish statistically useful baseline data on the critical ecosystem components, processes and services (i.e. ecological character) of the wetland system. Monitoring key environment indicators (e.g. water quantity, water quality, selected aquatic flora and fauna populations) will help to design more targeted management plans to maintain ecological character of the DIWA site.
6. Additional investigations on refuge value for fauna populations, and further counts of waterbirds, should be conducted to improve the evidence on how the DIWA site may meet Ramsar Criteria 4, 5 and 6.

Specific recommendations on immediate action to maintain biodiversity and improve overall ecological condition of these wetlands include:

1. A balanced management of controlling cattle access to wetlands, plus control of feral pigs, would contribute to protecting and enhancing the ecological condition and values of these wetlands.
2. Control of feral cat and fox populations would reduce their adverse impacts on populations of native fauna, particularly skinks, birds and mammals.
3. Recent invasions of cats claw vine and the serious environmental and pasture weed lippia, *Phyla canescens,* are still limited in extent here, but could move into a rapid expansion phase under climate or irrigation regimes that produce more regular watering. They should be monitored and controlled early to avoid future increases in cost and efficacy of controls, adverse impacts on native flora, fauna and cattle production if further spreading occurs.
4. Other invasive weeds, particularly through cropping areas and cleared habitats, should be monitored and targeted for potential control programs as needed.

5. Improving and maintaining ground cover on floodplains would help to minimise landscape erosion, reduce sediment infilling of wetlands and streams and reduce local cumulative impacts on the Dawson catchment (also see knowledge gap #2 above).
6. Supporting fish migration through use of more effective fish passage facilities on existing barriers and avoiding construction of additional barriers) will benefit the biodiversity values of these wetlands as well as several other important parts of the upper Dawson catchment.
7. Adapting to new pressures associated with climate change will require efforts to improve soil, water and vegetation at the whole-of-catchment scale. Adaptations and changes in land use, to be most effective for landholders and wetland ecosystems alike, may require coordinated efforts across the whole catchment.

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Glossary and Acronyms

ARI	Average Recurrence Interval (e.g. 1 year ARI events occur on average once every year)
AUSRIVAS	Australian River Assessment System
Alluvium	Alluvium Consulting Australia Pty Ltd
Coliform bacteria	A type of bacteria commonly found in the aquatic environment, in soil and on vegetation
FBA	Fitzroy Basin Association Inc.
Hyporheic	The zone beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water
nMDS	Non-metric multidimensional scaling
PET taxa	Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies)
QWQG	Queensland Water Quality Guidelines
DSEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
WQO	Water Quality Objectives

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1 Introduction

1.1 Background

The Palm Tree Creek and Robinson Creek wetlands are classified as a nationally important wetland area in the *Directory of Important Wetlands in Australia* (DIWA) (DEHP 2013a, Environment Australia 2001). The DIWA site includes Lake Murphy Conservation Park (along the lower reaches of Robinson Creek), a protected area under Queensland legislation. This large wetland system is located approximately 28km north of the town of Taroom in the upper Dawson Sub-Catchment (Fitzroy Basin), Queensland. To date, it has received very little formal study.

A project was initiated to enhance our understanding of critical environmental assets in the Fitzroy Basin, specifically in the Palm Tree Creek and Robinson Creek wetlands. A sub-project on wetland ecology contributes to a broader study by FBA that investigates the biophysical, social and cultural values of this part of the Dawson River catchment and Fitzroy Basin. These studies will lead to the formulation of local management guidelines to maintain and enhance the values of these wetlands into the future.

Alluvium Consulting Australia Pty Ltd (Alluvium) was commissioned by Fitzroy Basin Association (FBA) to undertake assessments of hydrology, aquatic fauna and local perceptions of the natural history of the Palm Tree Creek and Robinson Creek Wetlands. This report summarises the findings of those studies, also incorporating the results of a separate study on plants at these wetlands, conducted by the Queensland Herbarium, with support funds from FBA (Halford *et al.*, In Prep).

Funding for the current suite of preliminary studies was primarily from the Australian Government's *Biodiversity Fund*, under the Clean Energy Future program with additional support from Santos. The project also received in-kind technical support from Alluvium and the Queensland Herbarium.

1.2 Purpose

This study was designed to provide the first general description of wetland ecology for the Palm Tree Creek and Robinson Creek wetlands DIWA site. As a preliminary study it will generate key recommendations for ecological management, plus identify knowledge gaps requiring priority attention. This report will be used with other related studies of the Palm Tree Creek and Robinson Creek wetlands to inform community education and awareness programs and to develop management options for maintaining the wetlands' environmental values and ecosystem services.

1.3 Scope

Although streams are also classed as wetlands, the abundant floodplain palustrine (swamp) and lacustrine (lake) wetlands were the focus of attention in the *Palm Tree Creek and Robinson Creek Wetlands* DIWA site and are thus the key subject of this study.

Resource allocations enabled only a limited period and intensity of surveys across the wetland system (see Methods section for details). The hydrological study uses a combination of historical rainfall, stream gauging, Landsat and terrain data. The field survey results are derived from a single set of sampling events in the post-wet season period (March - May 2013), conducted at 50 wetlands for flora and 8 wetlands for aquatic fauna. Surveys and reports on wetland birds (Briggs 2013) and terrestrial fauna (Fauna Track 2013) were conducted separately to this study.

Inferences from the study results should therefore be made with appropriate caution, with limited or no capacity to comment on detailed ecological community compositions, or seasonal and year-to-year changes in flora, fauna and some important ecological processes. The hydrology study, based on recent decades of rainfall, gauging station and Landsat data, offers some insights into seasonal and year-to-year change, but future changes under climate variability are not easily predictable. A limited set of priority recommendations is provided at the end of this report for addressing knowledge gaps and for management planning and action.

1.4 Study Area

The Palm Tree and Robinson Creeks wetland system covers an area of 50 223ha and is characterised by a series of shallow lakes and seasonal streams (DSEWPaC 2010) (Figure 1). This system is located within the upper Dawson River catchment in the south-western portion of Queensland's Fitzroy Basin. The closest urban centre (approx. 28km to the south) is the township of Taroom, in Banana Shire, which has a population of 629 (Banana Shire Council 2012).

The Palm Tree and Robinson Creeks wetland site (#QLD018) is listed in the *Directory of Important Wetlands in Australia* on the basis of meeting two criteria:

- It is a good example of a particular wetland type occurring within a biogeographic region in Australia, and
- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level (DSEWPaC 2010).

The study area falls within the 'Brigalow Belt South' bioregion – one of Australia's 89 bioregions (DSEWPaC 2013). The Brigalow Belt South bioregion includes undulating to hilly areas with low ridges and deep valleys, as well as flat alluvial plains in the south. Vegetation is predominantly mixed eucalypt woodland with areas of brigalow scrubs and (before agricultural development) open grasslands (Bastin 2008, Australian Natural Resources Atlas 2009). The term 'brigalow' is used alternately to refer to:

- the tree *Acacia harpophylla* – a wattle tree with silvery foliage that grows as forests or woodlands on clay soils;
- an ecological community dominated by this tree; or
- a broader region where this species and ecological community are present (Threatened Species Network 2008).

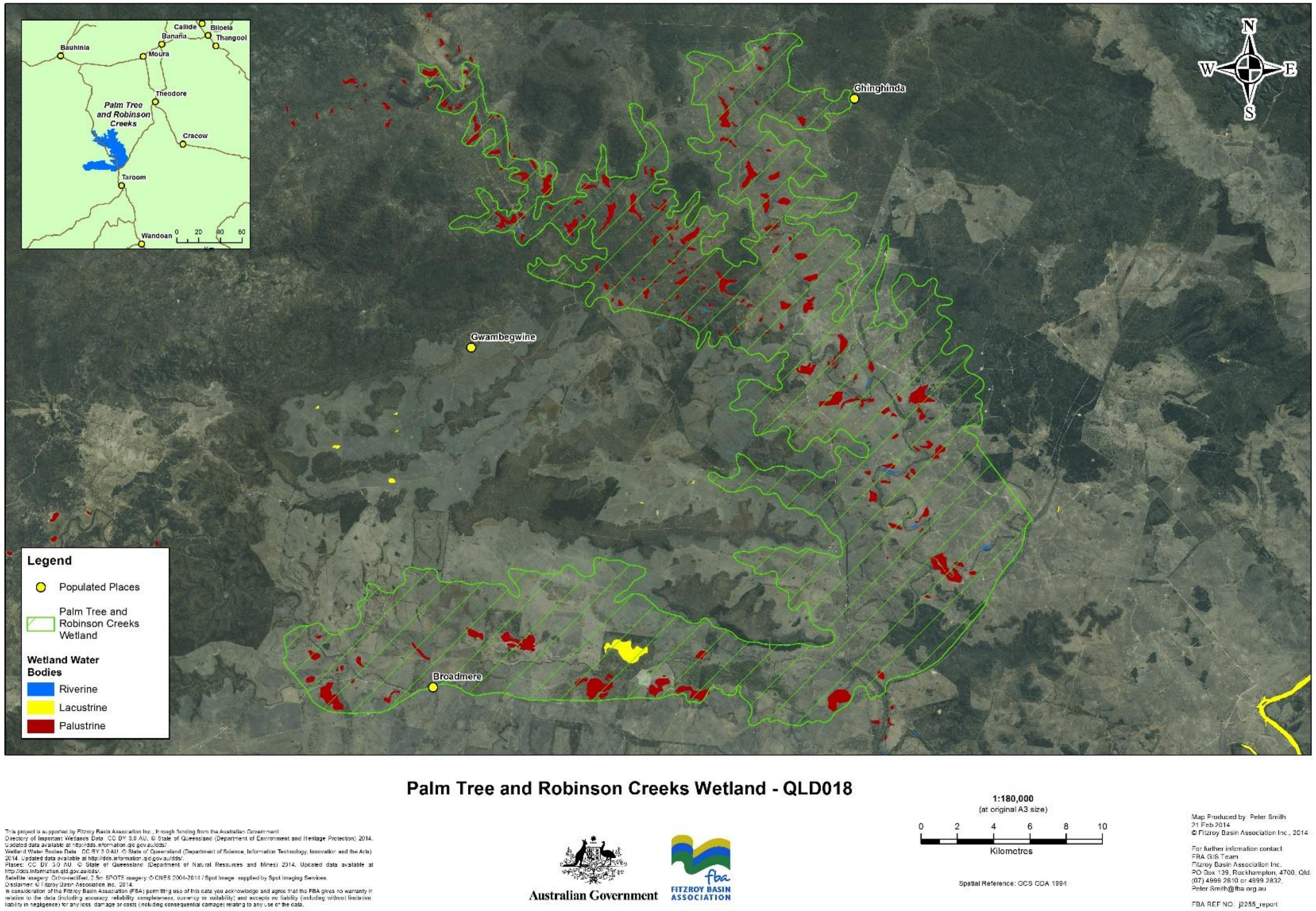

Figure 1 Project study area: Palm Tree Creek and Robinson Creek wetlands DIWA site (Source: FBA).

Most brigalow dominated communities occur on 'gilgai-ed clay vertosols'. These are shrink-swell soils, which form Gilgais - a distinctive, micro-relief geomorphic feature of the Brigalow Belt South, comprising networks of alternating mounds and depressions that intermittently fill with water following rainfall events (DERM 2011). The Palm Tree Creek and Robinson Creek catchments however are located on mostly sandstone and clay soils, thus neither brigalow vegetation nor the typical gilgai vertosol soils and gilgai wetlands are prominent at this location.

The species of palm found in the study area, and that gives Palm Tree Creek its name, is referred to variously as *Livistona nitida* (Queensland Parks and Wildlife Service 2001) and *Livistona sp.* unnamed (DSEWPaC 2010), and commonly as Carnarvon Gorge cabbage palm, Carnarvon fan palm, cabbage tree palm or Dawson palm. It is common in Carnarvon Gorge where it grows along stream banks and on rocky escarpments, frequently associated with eucalyptus forest areas (Rodd 1998).

1.5 Landuse

Details of the region's early pioneering days are described by Rechner (2003), e.g.: "*The early pioneers of the Taroom district ran sheep from the 1840s. In the 1870s landholders started selling their sheep in favour of cattle*."

Today cattle grazing on pastoral leases remains the dominant land use in the study area (Bastin 2008), including native pasture and introduced pasture grazing (Figure 2). Natural wetlands are used as water resources for stock, as well as being valued for their recreational and scenic amenity. Lower parts of the Robinson Creek catchment have been cleared and cultivated for cropping.

Coal and coal seam gas industry activities presently do not occur in the study area, although a substantial and growing coal seam gas exploration and extraction industry occurs across the region. Open-cut coal mining has existed for several decades across the wider Dawson River and Fitzroy catchments and is a major economic driver for the region (Rechner 2003).

Figure 2 Cattle grazing - the predominant land-use in the Palm Tree Creek & Robinson Creek wetlands DIWA site.

2 Methods

Information used to develop this overview of wetlands ecology of Palm Tree Creek and Robinson Creek was obtained through the following separate studies:

Local Historical perspectives: Thirteen local residents, whose families have lived and worked by these wetlands for generations, were engaged to share their stories, personal recollections and family photo collections about the wetlands, during seven separate interviews conducted during March and April 2013 (Alluvium 2013a).

Hydrology: A desktop study of surface water hydrology was conducted by Alluvium using historical rainfall and stream gauge data, satellite imagery, RORB hydrological modelling, 2D flood modelling and local knowledge (detailed in Alluvium 2013b). Direct information on groundwater was scarce, enabling only limited inferences on the relative contributions of groundwater to the wetlands. Simple hydrological models were developed to describe the seasonal and long-term nature of wetland inundation and flooding.

Aquatic fauna: Eight palustrine wetlands in the system were surveyed by frc environmental for aquatic fauna in April 2013 (frc environmental 2013). The 8 aquatic fauna sampling sites were selected to represent a range of wetland sizes and wetland types and to include wetlands from upper, middle and lower portions of the Palm Tree Creek and Robinson Creek catchments. These surveys used methods in the Queensland AUSRIVAS sampling manual for macroinvertebrates and a combination of backpack electrofishing, baited traps and seine nets to sample fish communities (Detailed in the aquatic fauna report: frc environmental 2013).

Wetland flora: In a separate study commissioned by the FBA, approximately 50 wetlands across the site were surveyed by the Queensland Herbarium for wetland flora (Halford *et al.*, In Prep). This was completed over 3 field trips during the period April-June 2013. The hydrological study modelled water balance and riverine interaction at 44 of these wetlands (Alluvium 2013b), whilst the aquatic fauna surveys included eight of these wetlands (frc environmental 2013).

Results of all 4 studies plus reviews of relevant literature were collated to develop general ecological descriptions and models for the wetlands, suitable for use in management planning for the DIWA site and for education.

3 Results and Discussion

3.1 Caveats on the results

This study included a mix of limited historical perspectives and data plus “snap-shot” studies relevant to autumn 2013. The study scope did not allow for detailed assessments of all aspects of wetland ecology (physical and biological processes), landscape features or land-use pressures.

As such, the synopsis of wetland system ecology for this area is broad in scope and limited in detail. Appropriate caution should thus be used when interpreting the information on wetland components, processes, functions and values, as well as threats and seasonal and long-term change.

The summary descriptions of these wetland ecosystems incorporate hydrological modelling with other key components and processes influencing the wetlands, for example: social, agricultural, geomorphological, climate, and biological. We use standard conceptual illustrations of these wetland types from the Queensland Government *WetlandInfo* webpages to help describe the key ecological components and processes.

3.2 Geomorphology and Geology

Geomorphology: The DIWA site is characterised by a series of shallow wetlands and seasonal streams associated with the junction of Palm Tree and Robinson creeks. The surrounding uplands are valley flats, and undulating hills with some relatively high relief.

The site includes a range of landforms that support occurrence of wetlands, including floodouts, drainage depressions, stream channels and stream beds. Most swamps and large lakes reach between 1 and 2m maximum depth. A few may contain slightly deeper areas and are semi-permanent. The catchment includes a number of minor streams which drain out of the Murphy and Lynd ranges west of the site, and of Palm, Box, Champagne, Punchbowl and Little Tualka creeks which drain out of the Gilbert Range to the north and east of the site.

The headwaters of these two sub-catchments include the eucalypt woodlands and forests of Expedition National Park and Palm Grove National Park. The upper-middle portions of the catchments are partially cleared for grazing. Mid and lower portions of the two catchments are more extensively cleared.

The confluence of Palm Tree Creek and Robinson Creek is approximately 19km upstream of where Palm Tree Creek enters the Dawson River. At several places downstream of here, connectivity to the Fitzroy River and Coral Sea is compromised by weirs and dams. The Nathan Dam, currently proposed and being assessed for construction on the Dawson River, would include a full storage level that reaches Palm Tree Creek above its junction with the Dawson River. At approximately 6km downstream of, and at least 5m altitude lower than the DIWA site, impacts on flow regime or deposition within the site may be minimal.

Surface geology: The lithology (surface rock features) of the Palm Tree Creek section of the DIWA site is predominantly Lower to Middle Jurassic argillaceous sublabile sandstone and quartzose sandstone. The lithology of the Robinson Creek section is predominantly Middle Jurassic calcareous lithic sandstone, calcareous siltstone shale, carbonaceous shale and coal overlain partially by Cainozoic soil and sand (DSEWPaC 2010).

Digital representations of distribution or extent of geological units, have been extracted from the Rock Units Table held in the Queensland Department of Natural Resources and Mines MERLIN Database (URL/service: http://mines.industry.qld.gov.au/geoscience/about-gsq.htm). Local observations accord with Queensland Government geological survey information. The wider catchment geology and soils are derived mostly from sandstone, siltstone and mudstone. However, the Palm Tree Creek wetlands are on coarser sandy geology and Robinson Creek wetlands are on thick deposits of alluvial clay, silt, sand, gravel and colluvial material (Figure 3). It may be this specific geomorphology that contributes to the regionally unique abundance of water pooling and wetland features "off-stream" of the main creeks, although further fluvial geomorphology studies would help address this knowledge gap.

Soils: Along the Palm Tree Creek section topsoils are hard setting loamy soils with mottled yellow clayey subsoils, and the Robinson Creek section includes loamy soils with weak horizon formation.

Climate: The site falls within the 610-711 mm rainfall isohyets. Rainfall at Taroom Post office (27km south) occurs over an average 47 days per year - mostly in summer (December-March) and occasionally during winter. Cycles of region-wide flooding and drought affect this location, as in many parts of central Queensland. Mean monthly minimum temperatures range from 5^{o}C in July to 20.6^{o}C in January. Mean monthly maximum temperatures range from 21^{o}C in July to 33.7^{o}C in January.

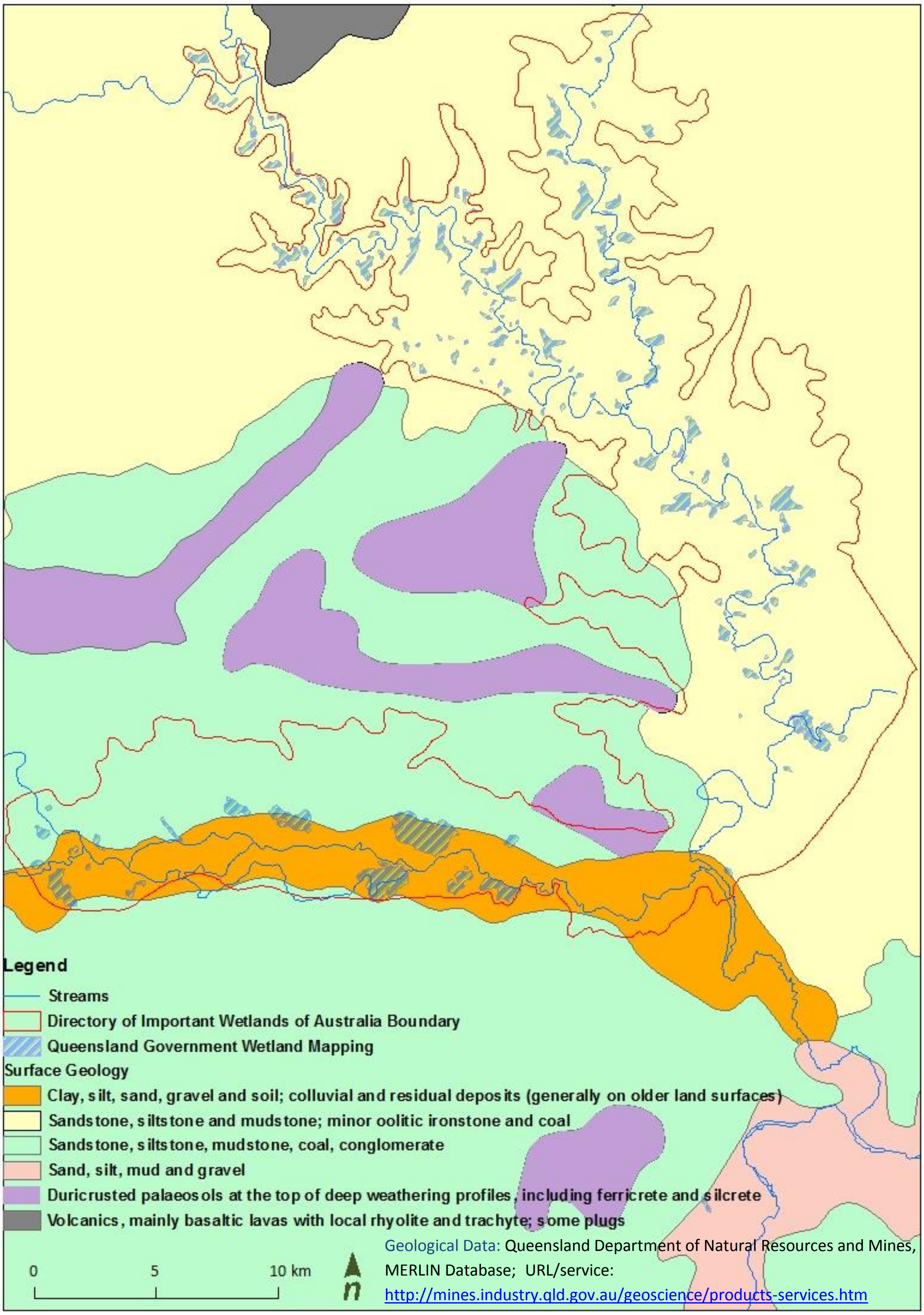

Figure 3 Surface Geology of the Palm Tree Creek and Robinson Creek catchments. (Geology Data Source: Queensland Department of Natural Resources and Mines, MERLIN Database).

3.3 Hydrology

Examination of Queensland Government wetland mapping (DEHP 2013a) revealed 154 non-riverine wetlands of 1ha minimum size within the DIWA site boundary[1] (Figure 4). Our analysis of Landsat images from a very wet year (2010-2011) identified at least 160 individual polygons (1ha minimum size) of inundated non-riverine wetland in the DIWA site boundary (Figure 4). These minor differences in total numbers of wetlands mapped may arise through mapping errors that lead to differences in the distinction of wetlands <1ha or >1ha in size. Some small wetlands detected in Landsat image analyses may at times appear as discrete wetlands and in other circumstances appear linked to other wetlands.

Palm Tree Creek sub-catchment supports at least 134 wetlands (from Queensland Government mapping data), mostly between 1ha and 10ha in size. Approximately 50 wetlands in the Palm Tree Creek sub-catchment are at least 10ha in size, with 5 of these between 50ha and 70ha in size. The Robinson Creek sub-catchment only supports around 20 individual wetlands, but 7 of these are relatively large (ranging between 50ha and 290ha) in area.

Local knowledge and recent survey teams confirm that most wetlands are only between 1 and 2m in depth. They fill after substantial rainfall events, which are usually greatest during summer monsoon months (November to March) but can extend into autumn (up to April, Figure 5). Peaks in wetland filling and extent have also occurred in winter months in some recent years (Alluvium 2014).

Whilst Queensland Government wetland mapping data indicates a total 2,527ha of non-riverine (lacustrine and palustrine) wetland, the total area of inundated wetland habitat (from analysis of Landsat imagery) in an average wet season can be around 4,000ha (Figure 5). Extreme wet events can result in approximately 9,000ha of inundated habitat once flood waters recede, as in December 2010 (Alluvium 2014), however much of this area may include riparian or floodplain habitat above the level of normal wetland extent.

Based on analyses of Landsat images, late dry season extent of wet area may decline to around 1000ha across the site during "average" rainfall years (Figure 5). During severe drought, total wet areas may only range between a few ha to 150 ha (Alluvium 2014).

2D modelling at selected wetlands estimated that approximately 50% of wetlands (primarily in the lower catchments) receive overflows from stream channels as frequently as 1-year ARI events (Alluvium 2014). Models also estimate that approximately 70% of wetlands receive riverine inflows under 10-year ARI events. Both these results are in general supported by local landholder observations. Wetlands in the upper catchments, particularly above the flat alluvial plains, receive less frequent riverine inflows. Water balance assessments indicate that local run-off sources may be relatively important to most wetlands, particularly those in the upper catchments.

[1] The DIWA boundary does not capture all wetlands within the catchment. A small number of minor floodplain wetlands occur immediately outside and upstream of the DIWA boundary.

Wetlands in the Robinson Creek catchment are fewer, mostly larger and often wet for longer periods than those in the Palm Tree Creek wetlands. Local landholder observations and regional surface geology mapping concur that slightly higher alluvial clay contents in the Robinson Creek wetlands may partly contribute to longer water retention periods, compared to the Palm Tree Creek Catchment where the geology is more sandy and wetlands appear to dry more quickly.

The seasonal and long-term wetting regimes (the wetland and stream hydrographs) in both catchments appear to be driven primarily by surface water contributions. The lakes and swamps are filled through a combination of local catchment and main stream (riverine) overflow, but most appear to rely on riverine overflows to achieve complete filling (Alluvium 2014).

Based on existing available information, the extent of groundwater contributions to water held in lakes and swamps appears small (see Alluvium 2014). However, some wetlands do not dry out as quickly as others, so groundwater contributions may be larger than expected in some areas. Further investigations are recommended to improve our currently inadequate understanding of groundwater resources, processes and influences in these streams and wetlands.

Local landholder observations suggest that sedimentation of some larger wetlands appears to be causing significant shallowing and expansion of wetlands, particularly on the alluvial plains of the lower catchments. Such changes may contribute to more widespread flooding during large rainfall events and are a concern for many landholders (Alluvium 2013, 2014). An adequate understanding of the causes of sediment accretion in wetlands would require more dedicated fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the landscape.

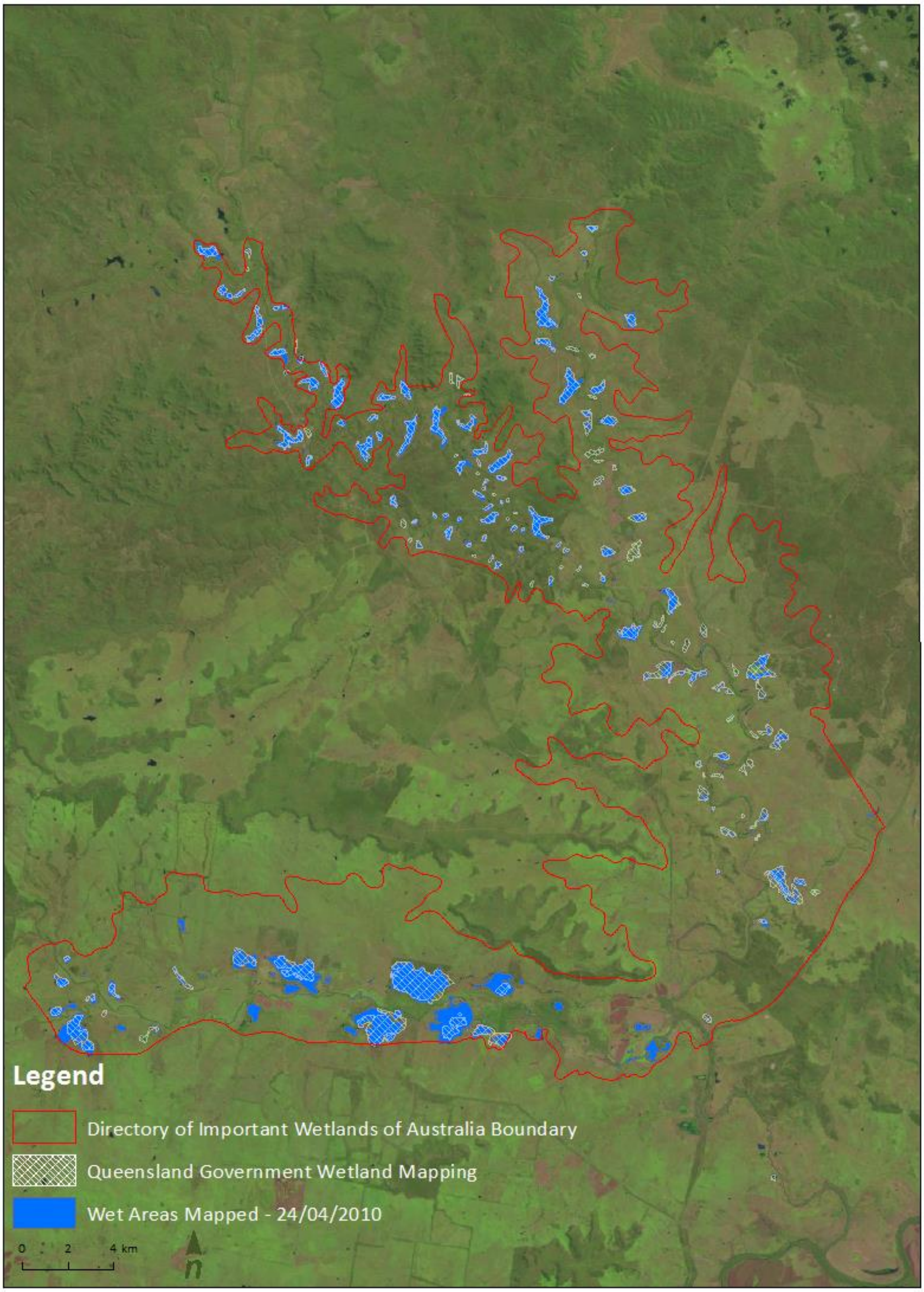

Figure 4 Landsat image analysis of inundated wetland habitat (Oct 2010) during an "above-average" rainfall year, plus overlay of Queensland government wetland mapping results (from Wetland*Info*).

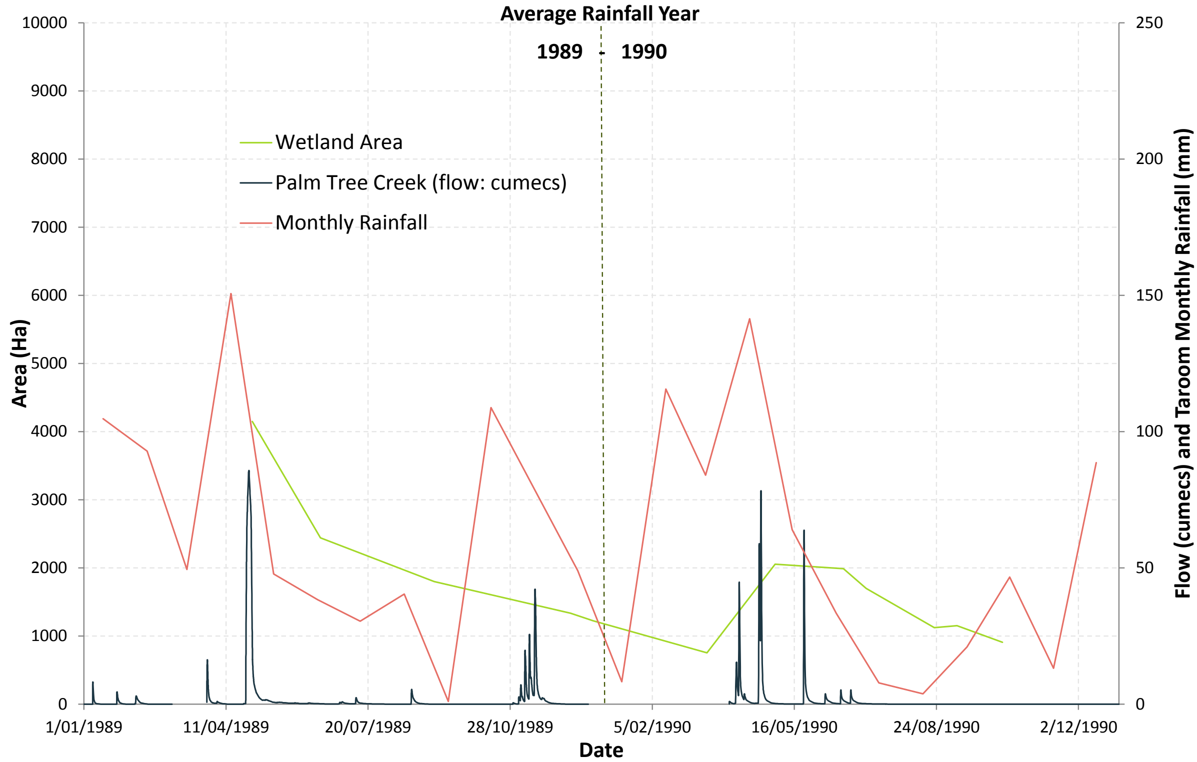

Figure 5 Estimates of wet (inundated) area during 1989/1990 – an "average" rainfall period.

3.4 Water Quality

Water quality records (for water temperature, conductivity, pH, turbidity and dissolved oxygen) from the single April 2013 sampling event at 8 wetlands provide only preliminary insights into the water quality conditions in relation to environmental values. The following observations should be used with caution until water quality can be assessed across more sites and over seasonal and inter-annual periods. For example, high rainfall events and sediment-laden flood waters from these grazed landscapes also cause temporarily higher water turbidity levels.

Although populations of native aquatic life were found in most wetlands, some water quality parameters were outside the acceptable ranges of Water Quality Objectives (WQO) for the upper Dawson catchment (frc environmental 2013, State of Queensland 2011). Turbidity levels exceeding Water Quality Objectives in some wetlands were associated with high disturbance from cattle, and low pH and dissolved oxygen levels in some wetlands possibly result from high loads of organic matter and biological oxygen demand. Electrical conductivity (i.e. salinity) in Robinson Creek wetlands did not meet WQO guidelines. The potential factors influencing electrical conductivity of water bodies include local geology, human impacts and groundwater influences. Water clarity in the wetlands was similar to, or often greater than, the clarity of water in the Dawson River, and was best in wetlands with well-established native wetland plants. High rainfall events and sediment-laden flood waters from these grazed landscapes also cause temporarily higher water turbidity levels.

3.5 Biological Assessments

3.5.1 Wetland Habitat and Flora

These wetlands predominantly support (in decreasing order) the palustrine and lacustrine wetland regional ecosystems 11.3.27g, 11.3.27d, 11.3.27c and 11.3.27 (see Appendix A for detailed descriptions). Wetland regional ecosystems are vegetation types mapped across Queensland for land management and conservation purposes (DEHP2013c). The regional ecosystem types at the Palm Tree Creek and Robinson Creek wetlands include open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. They are mapped to overlap in area reasonably closely to the non-riverine wetland maps. They are also widespread throughout the Brigalow Belt bioregion and their biodiversity conservation status is classified “Of Concern” (DEHP 2013c).

Patterns in wetland flora within the wetlands were generally similar throughout the DIWA site, nevertheless individual wetlands displayed particular floristic features according to their shape, topography and diversity of landforms. Most wetlands displayed a relatively high species richness of native wetland flora and riparian vegetation during post-wet flora surveys of 2013 (Halford *et al.* In Prep).

Halford *et al.* (In Prep) surveyed and identified eight broad groups of wetland flora comprising different bands or zones of vegetation in the wetlands. These descriptions provide greater detail of the within-wetland vegetation than that described by the regional ecosystem types.

Group 1	Shallow wetland with limited to no vegetation present
Group 2	*Eelgrass* (*Vallisneria nana)* and/or giant water lily (*Nymphaea gigantea*) deep (submerged or floating) aquatics
Group 3	*Yellow pea-bush* (*Sesbania cannabina, an introduced species*) tall herbland (thickets) on temporarily wet areas
Group 4	Shoreline herbland of terrestrial cosmopolitan species
Group 5	Tall spikerush (*Eleocharis sphacelata*) deep to shallow sedge swamp with Spiny mud-grass (*Pseudorhaphis spinescens*) and/or giant water lily (*Nymphaea gigantea*) sometimes subdominant
Group 6	*Water couch* (*Paspalum distichum*) and Water primrose (*Ludwigia peploides* subsp. *Montevidensis*) (both are introduced species) marginal aquatic grass and herbs
Group 7	*Ribbed spikerush* (*Eleocharis plana*) marginal aquatic sedgeland with *Ludwigia peploides* subsp. *montevidensis*, and/or *Pseudorhaphis spinescens*, and/or Nardoo (*Marsilea drummondii*) subdominant
Group 8	*Nardoo* (*Marsilea mutica*) and/or *Pseudorhaphis spinescens* shallow to marginal aquatics with *Ludwigia peploides* subsp. *montevidensis* subdominant

These were mostly found as bands or zones of vegetation occupying different levels and depths below the edge of terrestrial vegetation (the usual limit of inundation). The patterns of banding and species composition in wetland flora were generally similar throughout the DIWA site, except where wetland topography varied from the usual gently sloping depth gradient toward the centre (Halford *et al.* In Prep). The widths and vegetation types of these bands appear to be mostly influenced by topography, frequency of inundation and soil conductivity, and to a lesser extent soil pH (Halford, Drimer & Fensham *In Prep*).

Remote imagery shows that most wetlands still retain a belt of large trees around the perimeter of their riparian zone, although these appear to be declining in some agricultural areas and around large wetlands. Some locals have observed over several decades that sedimentation appears to be causing some large wetlands to become shallower and larger. This process may likely contribute to more frequent inundation and then death of terrestrial vegetation.

The extent of introduced flora species was surprisingly low at wetlands across the DIWA site. Nevertheless, invasions of cats claw vine (*Macfadyena unguis-cati*) along some stream riparian areas appear to be relatively recent (Halford *pers comm*), and Lippia (*Phyla canescens)* has existed in the area for several decades but is not yet widespread. Both species should be managed before widespread impacts occur and control becomes prohibitively expensive (see Threats section below).

3.5.2 Fauna

Macroinvertebrates

As ephemeral streams, swamps and lakes, the Palm Tree Creek and Robinson Creek wetlands support only a moderate diversity and abundance of aquatic macroinvertebrates and fish (frc environmental 2013). These communities are dominated by taxa that are tolerant of variable conditions (intermittent or slightly disturbed aquatic habitats), although most wetlands also had a small number of macroinvertebrate taxa that are relatively sensitive to variable conditions. As such, the diversity and abundance of aquatic habitats provided by this wetlands complex can potentially support aquatic macroinvertebrate communities that are slightly more species rich than wetlands in other parts of the upper Dawson Sub-Catchment.

Freshwater prawns (family Palaemonidae, *Macrobrachium australiense*) were the most widespread and abundant macrocrustaceans from surveys in April 2013 (Figure 6). Juvenile common yabbies (family Parastacidae, *Cherax* sp.) (Figure 7) and glass shrimp (family Atyidae, *Caridina* sp.) were caught in low numbers (frc environmental 2013).

Figure 6 Freshwater prawn caught at Wetland 12 in April 2013.

Figure 7 Common yabby caught at Wetland 7 in April 2013.

Fish

The species of freshwater fish caught in these wetlands were a sub-set of species that are typical and common in the upper Dawson Sub-Catchment. Most wetlands with fish supported all life-history stages, with juveniles, intermediates and adults all well represented. This indicated the importance of these wetlands for breeding by native fish.

Six native Australian species of fish were caught in April 2013 (frc environmental 2013), including:

- Agassiz's glassfish *(Ambassis agassizii)*(Figure 8)
- fly-specked hardyhead (*Craterocephalus stercusmuscarum*)
- carp gudgeon (*Hypseleotris* spp.) (Figure 9)
- spangled perch (*Leiopotherapon unicolor*) (Figure 10)
- eastern rainbowfish (*Melanotaenia splendida splendida*), and
- bony bream (*Nematalosa erebi*).

In addition to these, Hyrtl's tandan (*Neosilurus hyrtlii*) and yellowbelly (*Macquaria ambigua*) were recorded previously in Lake Murphy (Kelly 2011) but not found in the current study.

Two adult mosquitofish *Gambusia holbrooki,* declared a noxious species under the Fisheries Regulation 2008, were caught at one wetland (Figure 11). This highly adaptive and widespread pest species is known from stream and river habitats in the Dawson catchment and could occur more widely at times across the DIWA site. Another introduced species, Goldfish (*Carassius auratus*) was recorded from Lake Murphy in previous surveys (Kelly 2011).

There were no fish species listed as threatened under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* or Queensland's *Nature Conservation Act 1992* recorded in these surveys (frc environmental 2013) or previous surveys (Kelly 2011).

The most abundant and widespread species in 2013 were carp gudgeons and Agazzis's glassfish (frc environmental 2013). Other native species (i.e. gudgeons, spangled perch and rainbowfish) tend to be more abundant in riverine habitats throughout the upper Dawson Sub-Catchment.

Fish abundance was highly variable between wetlands. Highest fish abundance was found at sites with greatest abundance of aquatic plants. Sites in the upper catchment area of Palm Tree Creek had no fish, supporting conclusions of the hydrological study (Alluvium 2014) that wetlands in upper catchment areas are less connected to the main stream and are wet less frequently.

Taxonomic richness of fish communities was also variable between wetlands but moderately low across the whole wetland complex (up to only 4 fish species per site). Sites with greater abundance and diversity of aquatic plants and woody debris supported more species.

Figure 8 Agassiz's glassfish caught at Wetland 1 in April 2013.

Figure 9 Spangled perch caught at Wetland 14 in April 2013.

Figure 10 Carp gudgeon caught at Wetland 1 in April 2013.

Figure 11 Mosquitofish caught at Wetland 15 in April 2013.

Reptiles

Snake-necked turtle (*Chelodina longicollis*) was caught in two of the wetlands, and Krefft's River Turtle (*Emydura krefftii)* has previously been caught from Lake Murphy, indicating that at least two turtle species known from the upper Dawson Sub-Catchment inhabit these wetlands (frc environmental 2013). Snake-necked turtles are thought to prefer non-riverine rather than riverine habitats; thus, the abundance of this species could be relatively high in these palustrine and lacustrine wetlands. The white-throated snapping turtle (*Elseya albagula*), which occurs in the upper Dawson River catchment, was not caught in these surveys but is currently listed as least concern under Queensland's Nature Conservation Act 1992. It has been ranked as a species of high priority for conservation by the Department of Environment and Heritage Protection's species prioritisation framework, and is likely to qualify as an endangered species (Limpus et al. 2007).

Waterbirds

This project scope did not include formal study of avian wetland fauna. However a separate project dedicated to the avian fauna (Briggs 2013) demonstrated that these wetlands support a good diversity and abundance of wetland birds as well as non-wetland birds. General observations by locals and other survey teams (e.g. Kelly 2011) further support the evidence of Briggs (2013) that the site is important to several bird species for feeding, roosting, breeding, migration and/or refuge (see section on Ecosystem Services below).

Non-wetland fauna

In a separate study, surveys of terrestrial fauna in March and October 2013 identified almost 230 native vertebrate species in total, including mammals, birds, reptiles and amphibians (Fauna Track 2013). Appendix B below also provides an incomplete fauna list from earlier surveys targeted at Lake Murphy Conservation Park (Kelly 2011). The combined available data on species within the DIWA boundary indicates that the area supports a total of at least 37 native mammal species, 42 species of reptile and 15 species of amphibian (Fauna Track 2013).

3.6 Conceptual ecological models

This section provides an overview of the web of life and how it is sustained (i.e. the ecology) for the broad wetland types – as defined by the Queensland Wetland Program – occurring in the Palm Tree Creek and Robinson Creek wetlands. These descriptions are supported by generic conceptual diagrams of these wetland types, sourced from the Queensland Government's *WetlandInfo* webpages (DEHP 2013b).

Using the Queensland wetland mapping and classification methodology (Environmental Protection Agency 2005) and typologies (*http://wetlandinfo.ehp.qld.gov.au/wetlands)*, the palustrine (swamp) wetlands of the Palm Tree Creek and Robinson Creek DIWA site can be classified as "Coastal and subcoastal floodplain grass, sedge, herb swamp" (Figure 12). Being located in the drier, western parts of Queensland's sub-coastal region, these wetlands also display some characteristics of "Arid and semi-arid floodplain swamps".

Lake Murphy has been classified under Queensland Government mapping as a lacustrine wetland: "Coastal and sub-coastal floodplain lake" (DEHP 2013b) (Figure 13). These lakes are usually fringed by "Coastal and subcoastal floodplain grass, sedge, herb swamp" but this component is not mapped as a distinct unit if it is less than 50% of the wetland area. These large (>50ha) shallow lakes in the drier, western part of the coastal and sub-coastal region may also display some characteristics of "Arid and semi-arid floodplain lakes".

The lakes and swamps are fed by local creeks and the main streams or "riverine" habitats of Palm Tree Creek and Robinson Creek. These riverine wetlands were not intended as a focus for study in this project. They may be classified as: "Riverine wetland, Central Freshwater Biogeographic Province" under the Queensland wetland mapping and classification methodology (see Figure 14).

Conceptual diagrams help to explain how key physical and biological processes strongly link the geomorphology, hydrology, flora and fauna across these landscapes, streams and wetlands. A change in one component or process can create a range of changes in other elements of the system. Changes over recent decades in sedimentation, flooding patterns, abundance of wetland plants, certain fish species, etc, should be evidence of changes in these integral linkages.

These ecosystem models incorporate simplistic information on the geological, geomorphological, hydrological, biological and climatic components and processes influencing the wetlands. A more locally comprehensive description of the key ecosystem components, processes and ecosystem services provided by the catchment and wetlands system would form what is termed the "ecological character" of the Palm Tree Creek and Robinson Creek Wetlands.

This preliminary study does not include the scope to provide that comprehensive ecological character description. The generic conceptual diagrams below also do not include locally specific elements such as groundwater, water quality, social and agricultural uses, connectivity for migratory fish, etc. We suggest that locally appropriate conceptual diagrams should be developed to include additional influences on the wetlands, such as key social and agricultural uses, etc. These would be more useful in management, education and communication products to support maintenance of the site's ecological character.

Monitoring selected ecological indicators and threats is necessary to identify and assess for these changes. Any significant change (i.e. a change that is considered statistically greater that the normal range of variability for any particular ecological indicator) would be an early alert of potential adverse impacts on other critical processes (e.g. water exchange) and components (e.g. water quality, plants, animals). More detailed studies would be needed firstly to establish statistically useful baseline data on the critical ecosystem components, processes and services (i.e. ecological character) of the wetland system. Monitoring suites of key environment indicators and assessing any changes would then help to identify the likely causes of change. Information collected at this level of detail could more reliably inform action plans to maintain the critical ecosystem components, processes and services – i.e. the ecological character - for the DIWA site.

As an example, investigating the causes of sediment infilling in wetlands would require more dedicated fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the whole landscape. Addressing sedimentation through upstream erosion controls may also result in simultaneous improvements to wetland depth, water retention, flooding patterns, flora, fish and recreational amenity value at these wetlands.

The general conceptual models below provide examples which stakeholders and managers can use to understand these key interdependencies when developing management plans. Addressing knowledge gaps around particular ecosystem components and processes will enable more locally specific conceptual models to be developed and used for targeted management and education purposes.

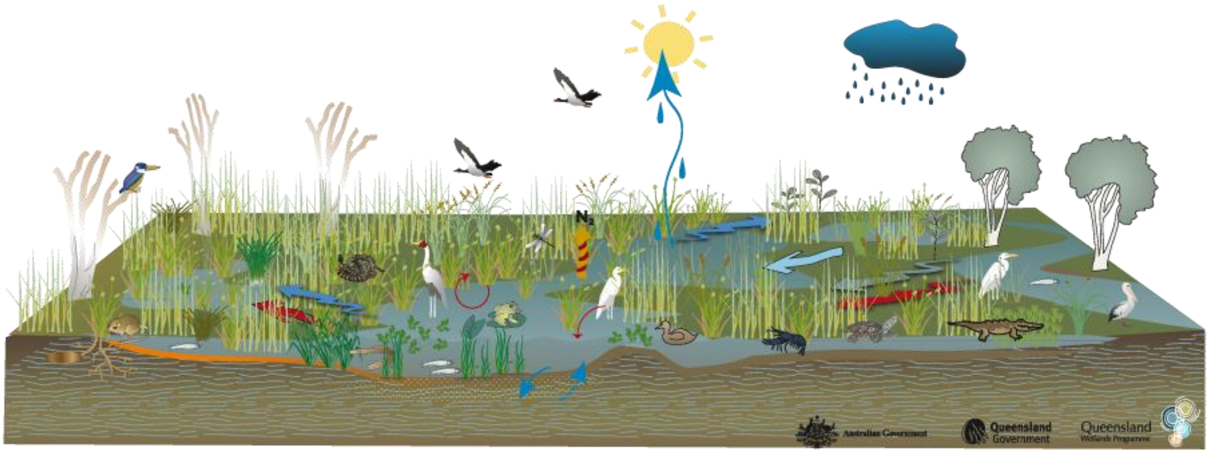

Figure 12 General conceptual model of palustrine wetland: "Coastal & subcoastal floodplain grass, sedge and herb swamp". Source: Queensland DEHP, *WetlandInfo < http://wetlandinfo.ehp.qld.gov.au/wetlands>*.

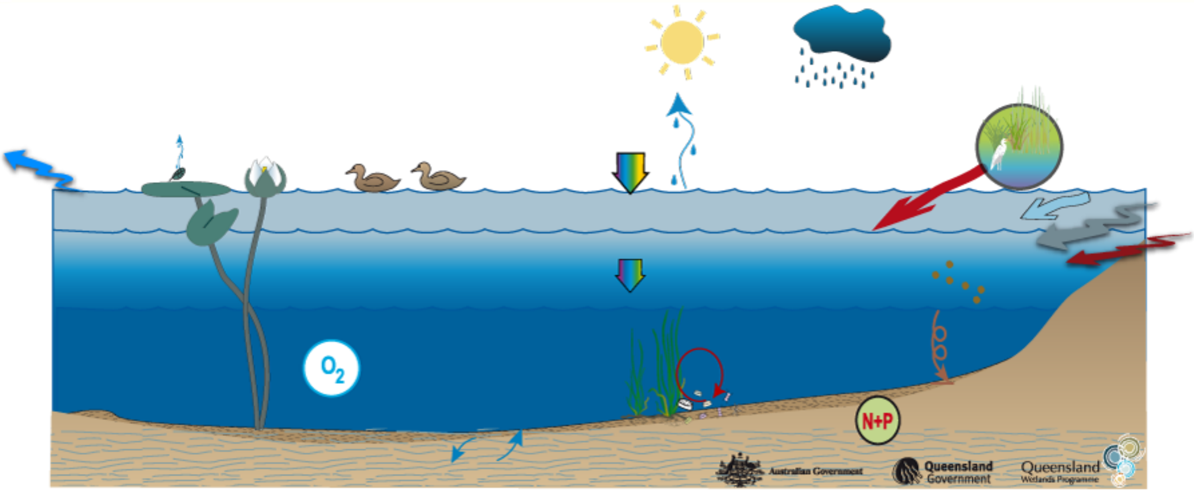

Figure 13 Conceptual model of lacustrine wetland: "Coastal and subcoastal floodplain lake". Source Queensland DEHP, *WetlandInfo* <http://wetlandinfo.ehp.qld.gov.au/wetlands>.

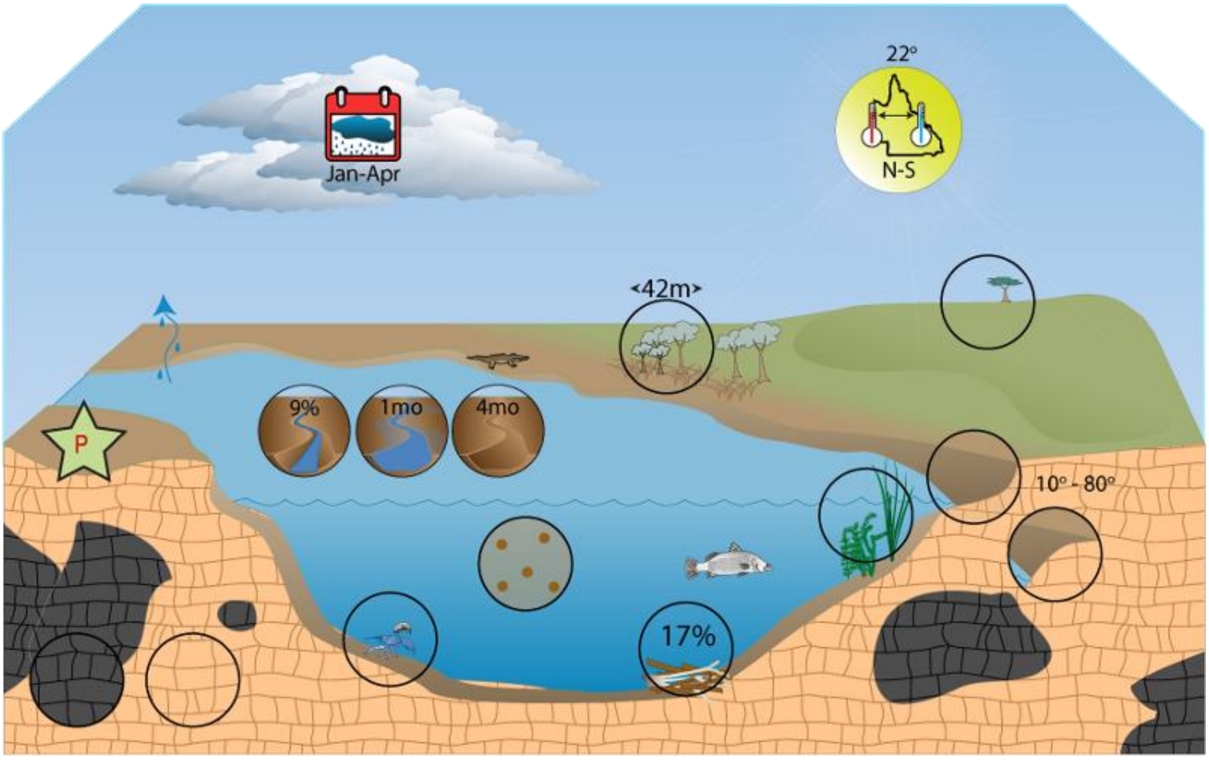

Figure 14 Conceptual model: riverine wetland, Central Freshwater Biogeographic Province. Source: Queensland DEHP, *WetlandInfo* < http://wetlandinfo.ehp.qld.gov.au/wetlands>.

3.7 Ecosystem Services

The palustrine and lacustrine wetlands of the Palm Tree Creek and Robinson Creek DIWA site provide several ecosystem services and values locally and of significance within the Brigalow Belt South bioregion and the Fitzroy River Drainage Basin. Some of these noted within this study include:

Regionally unique wetland complex

The Palm Tree Creek and Robinson Creek wetlands DIWA site provides a large aggregation of natural, semi-permanent, freshwater swamps and lakes concentrated in a single sub-catchment of the upper Dawson River catchment. The concentrated aggregation, geomorphology, hydrology and biological characteristics of these wetlands creates a localised wetland system that is not well represented on this scale elsewhere in the Fitzroy River Drainage Basin and the Brigalow Belt South bioregion. In this respect, the site meets national criteria, and potentially international criteria, for uniqueness:

DIWA Criteria 1: *It is a good example of a wetland type occurring within a biogeographic region in Australia.*

Ramsar Criteria 1: *A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region (Ramsar Convention 2012).*

Note that although a wetland site may be considered to meet criteria for listing as a wetland of international significance, the site can only be recognised as a Ramsar site if a formal nomination is submitted and successful for the site's inclusion on the Ramsar List of Wetlands of International Importance.

Diverse and abundant native wetland flora

Most of the surveyed wetlands contain mostly open shallow water with areas of submerged or floating aquatic vegetation, plus stands of native emergent wetland plants (sedges, reeds) along some margins or as isolated patches, and shoreline bands of wetland grasses and annual forb thickets. While located within a landscape with long grazing history, the extent of introduced flora was surprisingly low at wetlands across the DIWA site (Halford, Drimer & Fensham *In Prep*).

The wetland regional ecosystems 11.3.27g, 11.3.27d, 11.3.27c and 11.3.27 represented here include open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. They are widespread throughout the Brigalow Belt bioregion and their biodiversity conservation status is classified "Of Concern".

The autumn 2013 flora surveys of 50 wetlands identified 8 groups or community types of wetland flora, mostly comprising forbes, wetland grasses, sedges and rushes, water lilies, nardoo and vallisneria (Halford, Drimer & Fensham *In Prep*). They often occurred in bands or zones of vegetation occupying different levels and depths below the edge of terrestrial vegetation.

The abundance and diversity of native wetland plants in the wetland riparian zones and submerged areas helps to filter sediments and nutrients before they enter river systems. They also provide abundant good quality habitat and food for aquatic macroinvertebrates, fish, turtles and waterbirds.

Habitat for aquatic fauna

Overall, surveys indicate that the ecological value of the DIWA site wetlands in terms of aquatic fauna and flora is moderate to high (frc environmental 2013; Halford et al *In Prep*). Most wetlands had a reasonably high diversity of native aquatic plants (such as lilies, sedges, submerged species and aquatic herbs), providing a wide range of habitat types for aquatic fauna (macroinvertebrates, fish) to shelter and feed among (including large woody debris, epiphytes and sub-aquatic vegetation). Wetlands were of particularly high ecological value to aquatic fauna if they also provided diversity through shallow and deep pools, large wood snags (e.g. fallen trees), plus a diverse range of submerged, emergent and floating aquatic plants (frc environmental 2013).

This project scope did not include formal study of avian wetland fauna, as these are the subject of a separate project (Briggs 2013). General observations and literature searches (e.g. Kelly 2011) indicate that these wetlands support a good diversity and abundance of wetland and non-wetland birdlife.

Waterbirds are a conspicuous part of the site's wetland fauna, and reflect the overall condition of wetlands in terms of food availability, support to breeding and provision of roosting habitat. An incomplete list of waterbirds and other birds recorded from previous surveys at the wetlands is in Appendix B. More recent and extensive counting surveys of the site's avian fauna (Briggs 2013) reported 142 bird species within the DIWA site, adding a further 88 species to previous lists. Black swans, brolgas, ducks, teal, coot, herons, pelicans, darters, cormorants and others feed on different plants and animals in the wetlands. Migratory and resident shorebirds (waders) feed in the shallow waters and moist shorelines. In years of good rainfall, the site is used for breeding by species such as black swan, masked lapwings, black-fronted dotterel, grey teal and Eurasian coot.

Waterbird counts in 2013 (Briggs 2013) covered approximately 10% of available waterbird habitat in the DIWA site. Modest extrapolations of the counts indicate that the site would likely meet Criteria 5 for listing under the Ramsar Convention: "*a wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds*". Similarly, the site potentially meets Ramsar Criteria 6, if "*it regularly supports 1% of the individuals of the population of one species or sub-species of waterbird*". Recent sub-sample counts of Eurasian coot (*Fulica atra* sub-sp. *australis*) (Briggs 2013) indicate that the species most likely occurs across the DIWA site in numbers exceeding their 1% criteria. For this and other waterbird species, further surveys or expert opinion may help to establish whether such numbers occur here on a regular basis (e.g. every few years) sufficient for the site to meet these Ramsar criteria.

Habitat for threatened species

The site supports one non-wetland bird species (squatter pigeon, *Geophaps scripta*) declared as nationally vulnerable. The squatter pigeon, turquoise parrot and three waterbirds (cotton pygmy-goose, black-necked stork, freckled duck) are declared as threatened in Queensland (Briggs 2013). The koala (*Phascolarctos cinereus*), an iconic species and declared as nationally vulnerable, is also found within the site (Fauna Track 2013).

Refuge habitat

At times, when other regions are in drought, this large wetland complex may provide critical refuge for populations of many wetland species (particularly birds, fish, amphibians or freshwater turtles) occurring across inland Queensland. Some migratory species of fish or waterbirds may also depend on these wetlands for feeding and resting during parts of their life cycle. Further investigation may help to determine whether this role is sufficiently strong for the site to meet Ramsar Criteria 4: "*A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*".

Lake Murphy Conservation Park is surrounded by remnant terrestrial vegetation which has recently been excluded from grazing. Recent surveys of this single wetland identified a rich species list of native mammals, birds, reptiles, amphibians (Kelly 2011). Other wetlands surrounded by substantial areas of forest habitat within the Palm Tree Creek and Robinson Creek catchments could also provide conditions for maintaining reasonably good populations of native terrestrial fauna that would benefit from the wetland based food webs.

Water resource for stock

Cattle grazing on pastoral leases has been the dominant land use and economy derived within the DIWA site for more than 100 years, and the natural wetlands have always been used as a water resource and feeding area for stock.

Recreation and visual amenity

The wetlands provide attractive water-scapes and cool recreational areas for people during hot summer months (Figure 15). Since the commencement of European settlement, local landholders and visitors have used the wetlands for recreation such as bird watching, picnics, swimming and boating. The wetlands are particularly important to humans if they maintain their depth and water quality and continue to hold water for long periods. Investigations into the cultural heritage values of these wetlands to traditional indigenous landholders should provide useful additions to understanding the site's overall importance in the region. Traditional ecological knowledge and cultural heritage may also contribute additional management options for the site.

Figure 15 The wetlands possess high biodiversity, water resource, scenic and recreational values.

3.8 Critical processes and linkages

The climatic, geomorphological and hydrological characteristics of this site help govern the amount and quality of water delivered to wetland areas, which in turn influences the potential range of plants and animals that can survive here. The major drivers with potential to modify the character of the wetlands are human uses of land and water resources and changes in climate (see Threats and Impacts section below).

The filling of the Palm Tree Creek and Robinson Creek wetlands appears to be dominated by surface water hydrology, including 1) riverine flooding from Palm Tree Creek and Robinson Creek and 2) filling from local runoff and small streams (Alluvium 2014).

Whilst groundwater appears to have relatively little influence on hydrology of these wetlands, the potential level of groundwater influence on parts of the system should not be discounted (Alluvium 2014). If groundwater table levels and substrate permeability are suitable, local hyporheic flows of alluvial groundwater systems can lead to some level of base flow and potentially longer periods of wetland inundation (e.g. potentially at Lake Murphy and other wetlands in the lower catchment). Some wetlands and streams may instead leak into and recharge the local hyporheic shallow groundwater systems, and this may lead to drying out of these surface water bodies.

Wetlands of the DIWA site characteristically experience a strong seasonal wetting and drying cycle, but also undergo flood and drought cycles roughly every decade. Several components and processes will contribute to abundance and richness of wetland fauna within the wetlands, for example:

- water quality
- habitat connectivity and water exchange with the main creeks
- frequency and duration of wetting vs drying
- extent and quality of wetland habitat
- submerged wetland plants, emergent sedges and other fringing vegetation
- diversity of aquatic habitats (woody snags, plants for shelter and feeding, etc).

When the above conditions are favourable, they support greater microbial, planktonic and macroinvertebrate life. These lower food chain components in turn support rich food webs and populations of herbivores and higher level predators, as described above.

3.9 Threats and Impacts

Drivers of "natural" change in the wetlands include natural climatic, geomorphological, hydrological and biological processes, but human land-use and changes in overall climate patterns create abnormal pressures on the condition and functional integrity of wetlands.

Erosion and Sedimentation: Most swamps and large lakes currently reach between 1 and 2m depth. A few may contain slightly deeper areas, but local landholders commonly note a trend of shallowing and widening (expansion) of wetlands over several decades, particularly in larger wetlands of the lower catchments. The local soils are naturally highly erosive, but grazing, reductions in vegetation cover, and modifications to drainage channels are among several possible causes of increased sediment delivery to the wetlands. To fully understand the causes and mechanisms of sediment accretion in wetlands would require more dedicated fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the landscape.

Cattle grazing: Cattle access was evident at all of the wetlands, with trampling of bed habitat in shallow sections of most wetlands, leading to disturbance of bed sediments, localised impacts to water clarity and some disturbance to aquatic plants at some wetlands. The prevailing conditions and impacts from cattle could change considerably according to seasonal and long-term flooding and drying cycles in the wetlands.

Sheep were initially grazed in the area from 1840 to the 1870s (Rechner 2003). Wetlands in these two sub-catchments have been open to access by cattle since the commencement of beef production in the late 19th Century. The wetlands are used as watering points and for feeding on surrounding vegetation. Use of the wetlands by stock animals can reduce the extent of some wetland plants, promote growth of others, disturb bottom sediments, and increase water turbidity, coliform bacteria and nutrient levels in these freshwater habitats. Use of fencing to restrict cattle access to water bodies has proved beneficial to production whilst improving environmental quality of other wetlands like these in the upper Dawson catchment (FBA brochure 2002). A balanced management of controlling cattle access to wetlands would contribute to protecting and enhancing the ecological values of these wetlands.

Feral animals: Feral pig populations have been present here since early 20th Century and fluctuate with regional variations in climate and food supply. Digging and feeding in the wetlands by feral pigs causes habitat damage and removal of wetland plants, re-suspension of sediments and increased turbidity, introduction of disease and parasites, and adverse impacts on wetland aquatic fauna. Feral cat, fox and wild dog populations have been increasing here and across much of inland Queensland, posing increasing threats to populations of native skinks, birds and mammals (Fauna Track 2013). Control of feral cat and fox populations would reduce the impacts on native animal populations.

Barriers to connectivity: Downstream of the study area, several weirs and dams create impediments to migratory movements of aquatic species. Supporting fish migration through use of more effective fish passage facilities on existing barriers and avoiding construction of additional barriers, will benefit the biodiversity values of these wetlands as well as several other important parts of the upper Dawson catchment.

According to local landholders, catches of large eels were once common in the large wetlands here, but have declined over recent decades. These were more likely the long-finned eel or marble eel, *Anguilla reinhardtii*. Although none were found in the current surveys, they do occur in other parts of the Fitzroy and Dawson catchments, and are common in eastern Australian rivers. Since long-finned eels must migrate to the Coral Sea to breed, then return upstream as juveniles, it is very likely that populations in these upper reaches have been compromised by the series of barriers now in place along the Dawson River.

Several aquatic species are seasonal migrants between upper and lower parts of the Dawson and Fitzroy catchments, and some require connectivity to the sea to complete their life cycle. Connectivity is critical for migratory movements or passive transport of other biological material, adult, larval or juvenile life stages. Fish and turtle movements between the upper Dawson system and lower estuarine and coastal waters are required in response to seasonal and drought conditions.

The proposed Nathan Dam would likely restrict movements even more. Installation of fish passage structures at dams and weirs will help considerably, but not completely provide the type and degree of connectivity needed for many species and key ecological processes.

Introduced aquatic fauna: Existing populations of the introduced mosquito fish *Gambusia holbrooki* appear to be small, but if expanded to greater proportions they could present threats to native species through competition for food and habitat.

Full Storage Level (FSL) of the proposed Nathan Dam will reach upstream to the Leichhardt Highway, immediately below the Palm Tree Creek and Robinson Creek Wetlands. Any exotic fish species introduced at such a dam would likely further colonise the Palm Tree Creek and Robinson Creek wetlands, and potentially impact on populations of native species.

Invasive plants: Invasive weeds around wetlands are not as common as expected, given the historical uses and current extent of cattle grazing over this landscape. Cropping in the lower catchments may present different and greater threats, and these should be investigated. Scarred patches of earth, roadsides, etc, support weed growth, and provide additional pathways for introductions of invasive weeds. However, apart from localised blooms of several "naturalised" and non-declared weeds in some wetlands and riparian zones, most pastures and wetland fringes appeared to support relatively few invasive weeds.

Introduced grasses, particularly buffel grass, have been planted on several properties in recent decades. These grasses burn hotter than native grasses and in turn further threaten native communities. Nevertheless, it appears that native grasses and woodland species are in relatively good condition, as several refuge areas of remnant habitat still exist over much of the landscape.

Invasions of cats claw vine (*Macfadyena unguis-cati*) along the stream riparian areas appear to be relatively recent (Halford pers comm), but should be addressed as early as possible before their control becomes more costly and less effective. Cats claw vine can grow profusely in moist but open areas, and potentially choke out or smother the foliage of native habitats and impeding germination of the plants they cover. Cats claw vine appears to have started at upstream sites, and is now present along some main streams.

The serious environmental and pasture weed lippia, *Phyla canescens,* which has existed in the catchment for several decades, is still limited in extent, but may move into a rapid expansion phase under climate or irrigation regimes that produce regular watering. It should be monitored and targeted for potential control programs. Lippia rapidly forms dense carpets preventing the growth of other riparian vegetation. This results in soil erosion, which decreases bank stability and degrades the overall health and quality of the waterway. As such, lippia can have major environmental impacts on riverbanks and waterways, and poses a serious threat to protected wetland areas (State of Queensland 2009). It is unpalatable to cattle and competes against pasture grasses, thus causing significant declines in grazing productivity across the neighbouring Condamine catchment (Leigh & Walton 2004).

Climate Change*:* Changes to climate patterns may lead to a range of other changes in the system. Depending on the nature of climatic change, a range of important local consequences may result, eg:

- Extremes in flood and drought events
- Changes in vegetation
- More extreme fires
- More extreme hydrological forces associated with flooding events
- Increased erosion of landscape and streams, causing sedimentation and infilling in wetlands
- More regular wetting and growth of invasive weeds such as lippia and cats claw vine.

Adapting to these potential drivers and changes will require efforts to improve soil, water and vegetation across the landscape – the same components that underpin the landscape's capacity to support agriculture. Adaptations and changes in land use, to be most effective, may require coordinated efforts across the whole catchment. Improving resilience to future large impacts can be helped through enhancing the diversity and adaptability of ecological and social systems; and the costs of managing for this can be far less than the costs of failure (Allen *et al* 2011).

4 Recommendations

Management planning and education programs to maintain ecological character of the Palm Tree Creek and Robinson Creek wetlands would benefit from addressing the following knowledge gaps:

1. Further investigations into alluvial and artesian groundwater resources and hydrology to understand their potential influence on springs, wetlands and streams in this catchment.
2. An adequate understanding of the causes and mechanisms of sediment accretion in wetlands requires more targeted fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the landscape.
3. Investigations into indigenous knowledge and cultural heritage at the site may improve understanding of the cultural values and contribute additional management options.
4. Addressing the knowledge gaps on particular ecosystem components and processes will enable more locally specific conceptual models to be developed and used for targeted management and education purposes.
5. More detailed studies are needed firstly to establish statistically useful baseline data on the critical ecosystem components, processes and services (i.e. ecological character) of the wetland system. Monitoring key environment indicators (e.g. water quantity, water quality, selected aquatic flora and fauna populations) will help to design more targeted management plans to maintain ecological character of the DIWA site.
6. Additional investigations on refuge value for fauna populations, and further counts of waterbirds, should be conducted to improve the evidence on how the DIWA site may meet Ramsar Criteria 4, 5 and 6.

Specific recommendations on immediate action to maintain biodiversity and improve overall ecological condition of these wetlands include:

1. A balanced management of controlling cattle access to wetlands, plus control of feral pigs, would contribute to protecting and enhancing the ecological condition and values of these wetlands.
2. Control of feral cat and fox populations would reduce their adverse impacts on populations of native fauna, particularly skinks, birds and mammals.
3. Recent invasions of cats claw vine and the serious environmental and pasture weed lippia, *Phyla canescens,* are still limited in extent here, but could move into a rapid expansion phase under climate or irrigation regimes that produce more regular watering. They should be monitored and controlled early to avoid future increases in cost and efficacy of controls, adverse impacts on native flora, fauna and cattle production if further spreading occurs.
4. Other invasive weeds, particularly through cropping areas and cleared habitats, should be monitored and targeted for potential control programs as needed.
5. Improving and maintaining ground cover on floodplains would help to minimise landscape erosion, reduce sediment infilling of wetlands and streams and reduce local cumulative impacts on the Dawson catchment (also see knowledge gap #2 above).

6. Supporting fish migration through use of more effective fish passage facilities on existing barriers and avoiding construction of additional barriers) will benefit the biodiversity values of these wetlands as well as several other important parts of the upper Dawson catchment.
7. Adapting to new pressures associated with climate change will require efforts to improve soil, water and vegetation at the whole-of-catchment scale. Adaptations and changes in land use, to be most effective for landholders and wetland ecosystems alike, may require coordinated efforts across the whole catchment.

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6 Appendices

Appendix A – Wetlands Regional Ecosystems mapped in the Palm Tree Creek and Robinson Creek Wetlands DIWA site.

Wetland Regional Ecosystem	Description	Notes	Area (ha)
11.3.27g	Lacustrine wetland (e.g. lake). Lakes with or without fringing *Eucalyptus coolabah* low open woodland. Occurs on closed depressions on floodplains associated with old drainage courses. (BVG1M: 34a)	Dominant in the Palm Tree Creek sub-catchment	1580
11.3.27d	Palustrine wetland (e.g. vegetated swamp). *Eucalyptus camaldulensis* and/or *E. tereticornis* woodland. A range of sedges and grasses occur in the ground layer including *Fimbristylis vagans*, *Myriophyllum striatum*, *Nitella pseudoflabellata* and *Pseudoraphis* sp. Occurs fringing large lakes. (BVG1M: 34a)	Equates to Lake Murphy mapped area.	291
11.3.27c	Palustrine wetland (e.g. vegetated swamp). Mixed grassland or sedgeland with areas of open water +/- aquatic species. Dominated by a range of species including *Eleocharis* spp., *Nymphoides* spp. and sometimes *Phragmites australis*. Occurs on closed depressions on alluvial plains that are intermittently flooded in inlands parts of the bioregion. (BVG1M: 34d)	Pre-dominant in the Robinson Creek sub-catchment	630
11.3.27	Vegetation is variable including open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. Occurs in a variety of situations including lakes, billabongs, oxbows and depressions on floodplains. (BVG1M: 34d)	Small palustrine wetlands mapped in the upper Robinson and Palm Tree Creek sub-catchments	26
TOTAL			**2527**

Appendix B – Fauna species identified from recent surveys of Lake Murphy and other wetland habitats, Palm Tree Creek and Robinson Creek Wetlands

Table 1 List of wetland (and riparian zone) fauna species identified from recent surveys of the Palm Tree & Robinson Creek wetlands.

Common Name	**Scientific Name *#†**	**Kelly 2011** (Lake Murphy Conservation Park)	**frc environmental 2013** (survey of 8 wetlands)
Invertebrates – Butterflies			
Black-spotted grass-blue	*Famegana alsulus alsulus*	✓	
Blue argus	*Junonia orithya albicincta*	✓	
Blue tiger	*Tirumala hamata hamata*	✓	
Cabbage white	*Pieris rapae rapae*	✓	
Caper gull	*Cepora perimale*	✓	
Caper white	*Belenois java*	✓	
Chequered swallowtail	*Papilio demoleus sthenelus*	✓	
Clearwing swallowtail	*Cressida cressida Cressida*	✓	
Common crow	*Euploea core corinna*	✓	
Common grass-blue	*Zizina labradus labradus*	✓	
Dainty swallowtail	*Papilio anactus*	✓	
Dusky knight	*Ypthima arctous arctous*	✓	
Evening brown	*Melanitis leda bankia*	✓	
Glasswing	*Acraea andromacha andromacha*	✓	
Green grass-dart	*Ocybadistes walkeri sothis*	✓	
Grey ringlet	*Hypocysta pseudirius*	✓	
Grey swift	*Parnara bada sida*	✓	
Large grass-yellow	*Eurema hecabe hecabe*	✓	
Large purple line-blue	*Nacaduba berenice berenice*	✓	
Lesser wanderer	*Danaus chrysippus*	✓	
Long-tailed pea-blue	*Lampides boeticus*	✓	
Lyell's swift	*Pelopidas lyelli lyelli*	✓	
Meadow argus	*Junonia villida calybe*	✓	
Monarch	*Danaus plexippus plexippus*	✓	
No-brand grass-dart	*Taractrocera ina*	✓	
Orchard swallowtail	*Papilio aegeus aegeus*	✓	
Pale-orange darter	*Telicota colon argues*	✓	
Purple line-blue	*Prosotas dubiosa dubiosa*	✓	
Scalloped grass-yellow	*Eurema alitha*	✓	
Small grass-yellow	*Eurema smilax smilax*	✓	

Small green-banded blue	*Psychonotis caelius taygetus*	✓	
Striated pearl-white	*Elodina Parthia*	✓	
Varied eggfly	*Hypolimnas bolina nerina*	✓	
White migrant	*Catopsilia pyranthe crokera*	✓	
Yellow admiral	*Vanessa itea*	✓	
Yellow palm-dart	*Cephrenes trichopepla*	✓	
Invertebrates – Dragonflies			
Aurora bluetail	*Ischnura aurora*	✓	
Blue skimmer	*Orthetrum caledonicum*	✓	
Common bluetail	*Ischnura heterosticta*	✓	
Pygmy wisp	*Agriocnemis pygmaea*	✓	
Short-tailed duskdarter	*Zyxomma elgneri*	✓	
Wandering percher	*Diplacodes bipunctata*	✓	
Aquatic Macrocrustaceans			
Freshwater prawn	*Palaemonidae*		✓
Common yabby	*Parastacidae*		✓
Glass shrimp	*Atyidae*		✓
Fish			
Bony bream	*Nematalosa erebi*	✓	✓
Hyrtl's tandan	*Neosilurus hyrtlii*	✓	
Eastern rainbowfish	*Melanotaenia splendida*	✓	✓
Agassiz's glassfish	*Ambassis agassizi*	✓	✓
Yellowbelly	*Macquaria ambigua*	✓	
Spangled perch	*Leiopotherapon unicolor*	✓	✓
Flyspecked hardyhead	*Craterocephalus stercusmuscarum*		✓
Carp gudgeon	*Hypseleotris spp.*		✓
Mosquitofish	*Gambusia holbrooki*†		✓
Goldfish	*Carassius auratus*	✓	
Frogs			
Common treefrog	Litoria caerulea	✓	
Broad-palmed rocketfrog	Litoria latopalmata	✓	
Emerald-spotted treefrog	Litoria peronii	✓	
Naked treefrog	Litoria rubella	✓	
Stony creek frog	Litoria wilcoxi	✓	
Striped burrowing frog	Cyclorana alboguttata	✓	
Barking frog	Limnodynastes fletcheri	✓	
Salmon-striped frog	Limnodynastes salmini	✓	

Spotted grass frog	Limnodynastes tasmaniensis	✓	
Scarlet-sided pobblebonk	Limnodynastes terraereginae	✓	
Ornate burrowing frog	Platyplectron ornatum	✓	
Beeping froglet	Crinia parinsignifera	✓	
Cane toad	Rhinella marina†	✓	
Reptiles			
Broad-shelled turtle	*Chelodina expansa*	✓	
Snake-necked turtle	*Chelodina longicollis*	✓	✓
Krefft's turtle	*Emydura macquarii krefftii*	✓	
a gecko	*Gehyra dubia*	✓	
Bynoe's gecko	*Heteronotia binoei*	✓	
Robust velvet gecko	*Oedura robusta*	✓	
a skink	*Anomalopus verreauxii*	✓	
a skink	*Carlia pectoralis*	✓	
Elegant snake-eyed skink	*Cryptoblepharus pulcher*	✓	
Common bearded dragon	*Pogona barbata*	✓	
Lace monitor	*Varanus varius*	✓	
Spotted python	*Antaresia maculosa*	✓	
Black-headed python	*Aspidites melanocephalus*	✓	
Common tree snake	*Dendrelaphis punctulata*	✓	
Keel back	*Tropidonophis mairii*	✓	
Yellow-faced whipsnake	*Demansia psammophis*	✓	
Eastern brown snake	*Pseudonaja textilis*	✓	
Birds			
Brown quail	*Coturnix ypsilophora*	✓	
Black swan	*Cygnus atratus*	✓	
Australian wood duck	*Chenonetta jubata*	✓	
Cotton pygmy-goose	*Nettapus coromandelianus**	✓	
Grey teal	*Anas gracilis*	✓	
Pacific black duck	*Anas superci/iosa*	✓	
Hardhead	*Aythya australis*	✓	
Australasian grebe	*Tachybaptus novaehollandiae*	✓	
Crested pigeon	*Ocyphaps lophotes*	✓	
Peaceful dove	*Geopelia striata*	✓	
Bar-shouldered dove	*Geopelia humeralis*	✓	
Tawny frog mouth	*Podargus strigoides*	✓	
Australian owlet-nightjar	*Aegotheles cristatus*	✓	

Australasian darter	*Anhinga novaehollandiae*	✓	
Little pied cormorant	*Microcarbo melanoleucos*	✓	
Australian pelican	*Pelecanus conspicillatus*	✓	
Black-necked stork	*Ephippiorhynchus australis*	✓	
White-necked heron	*Ardea pacifica*	✓	
White-faced heron	*Egretta novaehollandiae*	✓	
Nankeen night-heron	*Nycticorax caledonicus*	✓	
Straw-necked ibis	*Threskiornis spinicollis*	✓	
Pacific baza	*Aviceda subcristata*	✓	
White-bellied sea-eagle	*Haliaeetus leucogaster*	✓	
Whistling kite	*Haliastur sphenurus*	✓	
Wedge-tailed eagle	*Aquila audax*	✓	
Nankeen kestrel	*Falco cenchroides*	✓	
Brown falcon	*Falco berigora*	✓	
Brolga	*Grus rubicunda*	✓	
Australian bustard	*Ardeotis australis*	✓	
Masked lapwing	*Vanellus ml'les*	✓	
Galah	*Eolophus roseicapillus*	✓	
Sulphur-crested cockatoo	*Cacatua galerita*	✓	
Cockatiel	*Nymphicus hollandicus*	✓	
Rainbow lorikeet	*Trichoglossus haematodus*	✓	
Scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*	✓	
Red-winged parrot	*Aprosmictus erythropterus*	✓	
Pale-headed rosella	*Platycercus adscitus*	✓	
Red-rumped parrot	*Psephotus haematonotus*	✓	
Pheasant coucal	*Centropus phasianinus*	✓	
Channel-billed cuckoo	*Scythrops novaehollandiae*	✓	
Horsfield's bronze-cuckoo	*Chalcites basalis*	✓	
Southern boobook	*Ninox novaeseelandiae*	✓	
Pacific barn owl	*Tyto javanica*	✓	
Laughing kookaburra	*Dacelo* novaeguineae	✓	
Blue-winged kookaburra	*Dacelo leachii*	✓	
Forest kingfisher	*Todiramphus macleayii*	✓	
Sacred kingfisher	*Todiramphus sanctus*	✓	
Dollar bird	*Eurystomus orientalis*	✓	
Red-backed fairy-wren	*Malurus melanocephalus*	✓	
Weebill	*Smicrornis brevirostris*	✓	
White-throated gerygone	*Gerygone albogularis*	✓	

Yellow-rumped thorn bill	*Acanthiza chrysorrhoa*	✓	
Striated pardalote	*Pardalotus striatus*	✓	
White-plumed honeyeater	*Lichenostomus penicillatus*	✓	
Noisy miner	*Manorina melanocephala*	✓	
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*	✓	
Brown honeyeater	*Lichmera indistincta*	✓	
Brown-headed honeyeater	*Melithreptus brevirostris*	✓	
Blue-faced honeyeater	*Entomyzon cyanotis*	✓	
Noisy friarbird	*Philemon corniculatus*	✓	
Striped honeyeater	*Plectorhyncha lanceolata*	✓	
Grey-crowned babbler	*Pomatostomus temporalis*	✓	
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	✓	
White-bellied cuckoo-shrike	*Coracina papuensis*	✓	
White-winged triller	*Lalage sueurii*	✓	
Rufous whistler	*Pachycephala rufiventris*	✓	
Grey shrike-thrush	*Colluricincla harmonica*	✓	
White-breasted wood swallow	*Artamus leucorhynchus*	✓	
Grey butcherbird	*Cracticus torquatus*	✓	
*P*ied butcherbird	*Cracticus nigrogularis*	✓	
Australian magpie	*Cracticus tibicen*	✓	
Pied currawong	*Strepera graculina*	✓	
Willie wagtail	*Rhipidura /eucophrys*	✓	
Australian raven	*Corvus coronoides*	✓	
Torresian crow	*Coivusorru*	✓	
Leaden flycatcher	*Myiagra rubecula*	✓	
Restless flycatcher	*Myiagra inquieta*	✓	
Magpie-lark	*Grallina cyanoleuca*	✓	
White winged chough	*Corcorax melanorhamphos*	✓	
Apostle bird	*Struthidea cinerea*	✓	
Jacky winter	*Microeca fascinans*	✓	
Golden-headed cisticola	*Cisticola exilis*	✓	
Tawny grassbird	*Megalurus timoriensis*	✓	
Welcome swallow	*Hirundo neoxena*	✓	
Tree martin	*Hirundo nigricans*	✓	
Mistletoe bird	*Dicaeum hirundinaceum*	✓	
Double-barred finch	*Taeniopygia bichenovii*	✓	
Plum-headed finch	*Neochmia modesta*	✓	

Mammals			
Short-beaked echidna	*Tachyglossus aculeatus*	✓	
Squirrel glider	*Petaurus norfolcensis*	✓	
Greater glider	*Petauroides volans*	✓	
Common brushtail possum	*Trichosurus vu/pecula*	✓	
Eastern grey kangaroo	*Macropus giganteus*	✓	
Red-necked wallaby	*Macropus rufogriseus*	✓	
Swamp wallaby	*Wallabia bicolor*	✓	
Delicate mouse	*Pseudomys delicatulus*	✓	
Eastern chestnut mouse	*Pseudomys gracilicaudatus*	✓	
Water rat	*Hydromys chrysogaster*	✓	
House mouse	*Mus musculus*†	✓	
Cat	*Feliscatus* †	✓	
Rabbit	*Oryctolagus cuniculus* †	✓	
European brown hare	*Lepus europaeus* †	✓	
Pig	*Sus scrofa* †	✓	

Listed as threatened species under the Commonwealth Government, *Environmental Protection and Biodiversity Conservation Act (EPBC) 1999*

* Listed as a threatened species under Queensland's *Nature Conservation Act 1992*

† Introduced species (pest/ feral/ invasive)

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FITZROY BASIN ASSOCIATION

Hydrology Report

FITZROY BASIN ASSOCIATION

Our country, Our future

Hydrology Report – Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by Alluvium Consulting Australia for Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

Hydrology Report - Palm Tree & Robinson Creek Wetlands

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This report was prepared on behalf of FBA by Alluvium Consulting Australia

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Summary

The Palm Tree Creek and Robinson Creek Wetlands site is listed as a nationally important wetland in the Australian Government's *Directory of Important Wetlands in Australia* (DIWA site #QLD018). This system is located approximately 28km north of Taroom within the upper Dawson River catchment in Queensland's Fitzroy Basin. The DIWA site covers an area of 50,223 ha and is characterised by a series of shallow seasonal swamps, lakes and streams (SEWPaC 2010).

This study is one of a suite of investigations commissioned by the Fitzroy Basin Association Inc. (FBA) in the Palm Tree Creek and Robinson Creek Wetlands – including hydrology, aquatic fauna (frc environmental 2013), wetland flora (Halford *et al* In Prep)) and local perspectives on natural history of the wetlands (Alluvium 2013). The results of these separate investigations all contribute to improving our overall understanding of the hydrology and ecology of the wetland system, and will help to inform future management for the wetlands.

Aquatic Habitats

The 2009 Queensland Government wetlands mapping version 3.0 indicates 154 non-riverine wetlands within the DIWA site boundary. This includes approximately 1.9 km^2 of lacustrine (lake) wetlands and 24.1 km^2 of palustrine (swamp) wetlands. Almost all of the non-riverine wetlands are located very close or adjacent to the main streams, but also have their own local source catchments.

Queensland Government wetland mapping also includes 24.1 km^2 of riverine wetlands, including the main creek lines which contribute to hydrology and ecological connectivity of the non-riverine floodplain wetlands. However, the high density and abundance of floodplain palustrine (swamp) and lacustrine (lake) wetlands are the key features characterising the *Palm Tree Creek and Robinson Creek Wetlands* DIWA site and are the key focus for the current set of studies. As such, the terms "wetlands" or "non-riverine wetlands" used throughout these documents invariably refers to these palustrine and lacustrine wetlands.

Robinson Creek has a catchment area of approximately 1,840 km^2 while Palm Tree Creek has a catchment area of approximately 3,230 km^2. On a catchment area basis, Palm Tree Creek has a higher density of non-riverine wetlands.

Hydrologic Modelling

Simple hydrologic modelling was undertaken to estimate flood hydrographs across the study area for various events. RORB modelling which was used for this study is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce the hydrograph.

The events determined to be most relevant to the objectives of the study included the 1 year, 2 year, 5 year and 10 year Average Recurrence Interval (ARI) events. Less frequent (larger magnitude) events were not considered necessary to the study, since most data and local information confirmed

that the 10 year ARI events interact (through riverine flooding processes) with most of the non-riverine wetlands in the study area.

Results & Discussion

The DIWA site includes at least 154 wetlands 1ha or greater in size, comprising mostly palustrine (swamp) and at least one semi-permanent lacustrine (lake) habitat. Numerous wetlands smaller than 1 ha occur at times but have not been considered in mapping. Almost all of the wetlands are located on the floodplain, immediately connected and adjacent to the main streams, but also have their own local source catchments.

The 2D flood modelling produced flood extent estimates throughout the Palm Tree Creek & Robinson Creek Wetlands for 1 year, 2 year, 5 year and 10 year ARI events (see Figure 15 to Figure 21). Local landholder observations and Landsat images of historical flood extents in general support the broad patterns of flooding and interaction between non-riverine wetlands and streams estimated by the 2D model.

2D modelling applied to a selection of 44 non-riverine wetlands (those surveyed in 2013 for vegetation) estimated that approximately 50% of wetlands (primarily in the lower catchments) receive riverine overflows as frequently as 1-year ARI events (Figure 22). The models also estimate that 70% of wetlands receive riverine influence from 1-year ARI to 10-year ARI events. However, these insights into the frequency of riverine flooding of the wetlands are only indicative, due to the broad scale nature of data available to undertake hydrologic and 2D flood modelling.

Wetlands in the Robinson Creek catchment are fewer, mostly larger and often wet for longer periods than those in the Palm Tree Creek wetlands. Local landholder observations and regional surface geology mapping concur that slightly higher alluvial clay contents in the Robinson Creek system may partly contribute to the longer water retention periods in these lakes and swamps compared to the more ephemeral wetlands located on the coarse sandy soils of the Palm tree Creek Catchment. There also appears to be a reasonable correlation between wetlands sizes and their respective local catchment sizes.

The seasonal and long-term wetting regimes (the wetland and stream hydrographs) in both catchments appear to be driven primarily by surface water contributions. The wetlands are filled through a combination of local catchment runoff and main stream (riverine) overflow.

Based on existing available information, the magnitude of groundwater contributions do not appear to be substantial compared to the surface water contributions. However, some wetlands do not dry out as quickly as others, so groundwater contributions may be larger than expected in some areas. Based on distributions of springs and groundwater systems nearby to this catchment, the potential for future discovery of springs in the DIWA site or greater catchment may be limited but should not be overlooked. Further investigations are recommended to improve our understanding of groundwater resources, processes and influences in these wetland systems. The presence of GAB springs nearby to the site, plus increasing resource exploration and development in the region, reinforces the need for further hydro-geologic investigations into groundwater discharge in the study area, including a focus on potential links with the Hutton Sandstone as well as the Eurombah formations.

A recurring local observation of importance to the management of the wetlands was that the sediment supply in the system was changing the shape of the wetlands (generally larger and shallower) and that the stability of natural levees keeping water in the non-riverine wetlands had been impacted by this process. Sedimentation of large wetlands on the alluvial plains of the lower catchments may lead to more widespread flooding and alterations to watercourses during large rainfall events and are a concern for many landholders. It is therefore recommended that the geomorphology and sources of erosion and sediment transport in the catchment is investigated in more detail to help mitigate these threats.

With respect to the management of the Palm Tree Creek and Robinson Creek wetlands this investigation highlights the importance of good land management practices to minimise landscape and bank erosion. While the above summary will assist in the development of management guidelines for the Palm Tree Creek and Robinson Creek wetlands, details within the body of the report may be consulted to inform the development any management guidelines directed to specific sections or sites in the system.

Recommendations

Accuracy and reliability of findings from the current hydrological study are limited by the extent and quality of recorded surface water and groundwater data. Recommendations arising from the study are listed to help address these limitations as well as inform management planning for maintaining ecological values of the Palm Tree Creek and Robinson Creek wetland and stream systems:

1. Acquiring high resolution terrain data such as LiDAR data is recommended to enable more detailed surface water balance modelling, improve the accuracy of the hydrologic and 2D flood modelling and understanding of how the wetlands fill and drain.
2. Improved surface water gauged data (local rainfall and, most importantly, stream gauge data determined using accurate rating curves) in Palm Tree Creek in particular for which the gauged flow data was judged to be unreliable at both gauging stations.
3. If future predictions on Climate change are to be attempted, it would be dependent on revisions of the Queensland guidelines for factoring climate change into flood modelling (Queensland Government 2010) and review of the current Australian Rainfall and Runoff guidance (AR&R, Kuczera and Frank 2012).
4. Further investigations are needed to improve understanding of alluvial and artesian groundwater resources, processes and influences in these wetland systems, including a focus on potential links with the Hutton Sandstone as well as the Eurombah formations.
5. A dedicated fluvial geomorphology study will improve the understanding of sediment sources and explanations to wetland shallowing and expansion. If coupled with assessments of soils, vegetation cover and erosion across the landscape, this would also help to identify where in the catchment the problems can be more effectively mitigated.

6. This hydrological investigation has also highlighted the importance of good land management practices to minimise impacts of landscape and bank erosion during flood events, and the related threats discussed above.

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Glossary and Acronyms

Alluvium	Alluvium Consulting Australia Pty Ltd
ARI	Average Recurrence Interval (1 year ARI events occur on average once every year)
FBA	Fitzroy Basin Association Inc.
Hyporheic	The zone beneath and alongside a stream bed, where there is a mixing of shallow groundwater and surface water
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities

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1 Introduction

The Palm Tree Creek and Robinson Creek wetland system is listed under the *Directory of Important Wetlands in Australia* (DIWA). The closest urban centre (approx. 28km to the south) is the township of Taroom, in Banana Shire, which has a population of 629 (Banana Shire Council 2012). The wetland system is characterised by a series of shallow, seasonal lakes, swamps and streams, and has received very little formal study (SEWPaC 2010).

This hydrological study represents one of a suite of investigations commissioned by the Fitzroy Basin Association Inc. (FBA) including aquatic, terrestrial and avian fauna, wetland flora and local perspectives on natural history of the Palm Tree Creek and Robinson Creek Wetlands.

The results of these separate investigations will contribute to a technical report, including maps, models and photographs that will help an overall understanding of the wetlands ecology and hydrology. These studies will also contribute to:

- future non-technical publications, designed to shed light on the processes and values of the wetlands, which will be accessible to the broader community, and
- development of management guidelines for the wetlands (to be delivered by FBA, in partnership with landholders).

Funding for the current suite of preliminary studies was primarily from the Australian Government with additional support from the Santos GLNG Project. The project also received in-kind technical support from Alluvium Consulting and the Queensland Herbarium.

This project was initiated to enhance our ecological understanding of critical environment assets in the Fitzroy Basin. The project contributes to a broader study by FBA that investigates the biophysical, social and cultural values of this part of the Dawson River catchment and Fitzroy Basin. These studies will lead to the formulation of local management guidelines to maintain and enhance the values of these wetlands into the future, and which will be accessible to the broader community

1.1 Purpose

The hydrological study of these wetlands was tailored to produce simple 2-dimensional conceptual models of the Palm Tree Creek and Robinson Creek Wetlands. This hydrological study will provide a greater understanding of the surface water hydrology and draw conclusions from that on the relative role of sub-surface (groundwater) components to hydrology of the wetlands.

These models will be used with other ecological studies on the wetland vegetation and aquatic fauna, to develop overall conceptual models and understandings of the hydrology and ecology of the wetlands. The ecological overview will be presented in a separate report, and include simple conceptual models and text descriptions of the ecological assets, processes and values associated with the wetland system.

The combined reports may be used to develop management options for maintaining the wetlands' ecological functions and values and to inform locally relevant education and awareness programs.

1.2 Scope

The hydrological study uses a combination of historical rainfall, stream gauging, satellite imagery (Landsat) and terrain data. Much of this data is of low resolution and/or from limited time periods. This study offers some insights into seasonal and year-to-year change, but future changes under climate variability are not easily predictable. Inferences from the study results should therefore be made with appropriate caution. Relative contributions of groundwater to hydrology are inferred from the surface water and water balance models; however a paucity of information on local groundwater systems enables only limited capacity to comment on groundwater processes or their contributions to the wetlands.

1.3 Study area

The Palm Tree and Robinson Creeks wetland system covers 50,223 ha (SEWPaC 2010), and is located within the upper Dawson River catchment in Queensland's Fitzroy Basin.

The Palm Tree and Robinson Creeks wetland system (Figure 1) is listed in the Australian Government's *Directory of Important Wetlands in Australia* (#QLD018) for meeting two criteria:

- It is a good example of a wetland type occurring within a biogeographic region in Australia, and
- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level (SEWPaC 2010).

The study area falls within the 'Brigalow Belt South' bioregion. Bioregions are large, geographically distinct areas of land with common characteristics such as geology, landform patterns, climate, ecological features and plant and animal communities (SEWPaC 2013). The Brigalow Belt South bioregion contains mixed landscapes, including undulating to hilly areas with low ridges and deep valleys, as well as flat alluvial plains in the south. Vegetation is predominantly mixed eucalypt woodland with areas of brigalow scrubs and open grasslands (Bastin 2008).

Most brigalow dominated communities occur on 'gilgai-ed clay vertosols'. These are shrink-swell soils, which develop deep cracks when dry. Gilgai's (commonly known as 'melon holes') are a distinctive geomorphic feature of the Brigalow Belt South, comprising a series of alternating mounds and depressions that intermittently fill with water following rainfall events (DERM 2011, The University of Queensland 2009). The Palm Tree Creek and Robinson Creek catchments however are located on mostly sandstone and clay soils, thus neither brigalow vegetation nor the typical gilgai vertosol soils and gilgai wetlands are prominent at this location.

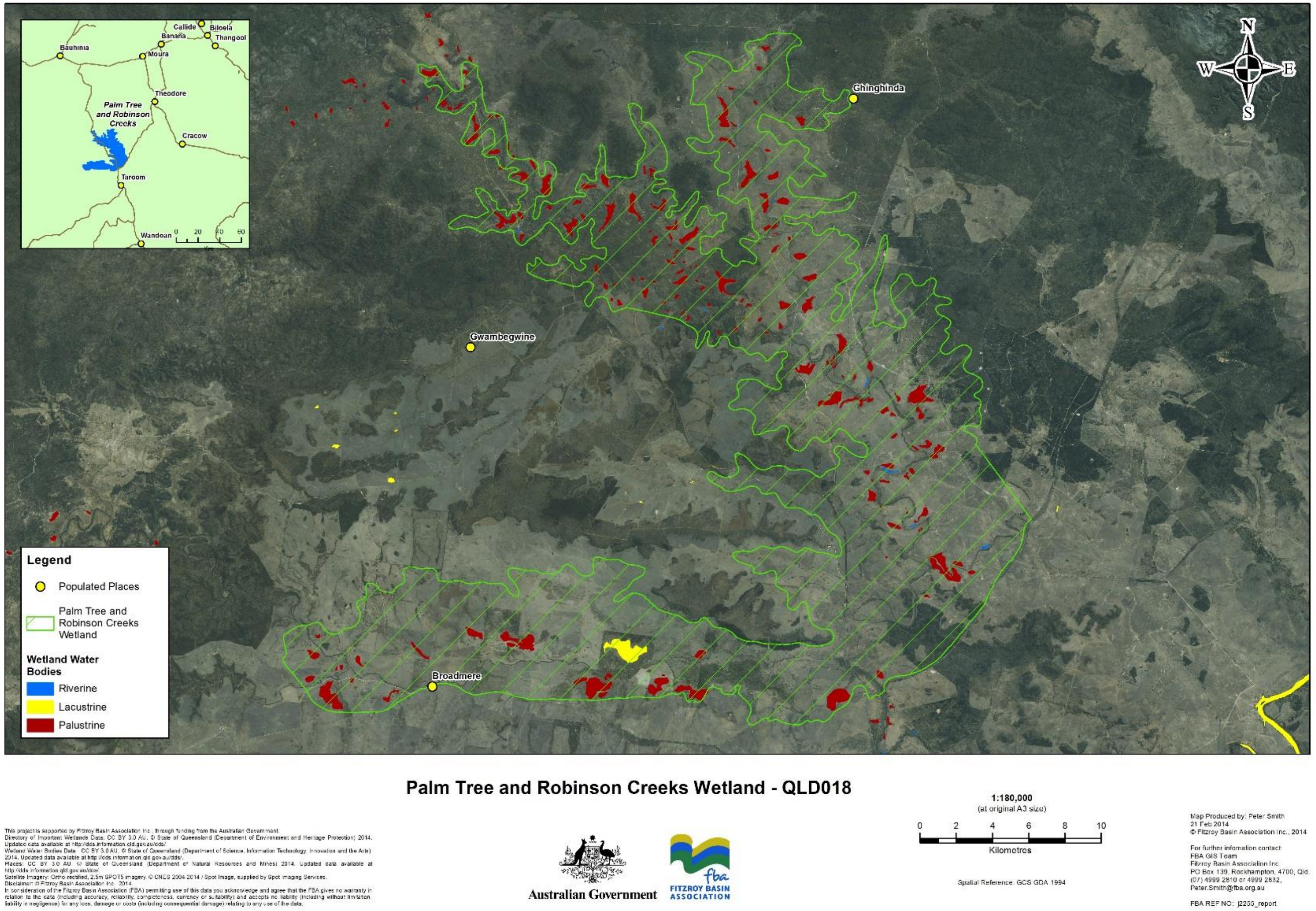

Figure 1 Project study area: Palm Tree Creek and Robinson Creek Wetlands (Source: FBA)

2 Methods

Pre-project scoping revealed very sparse information and evidence for groundwater hydrology in this system. The general approach in this hydrological study has thus been to develop a greater understanding of the surface water hydrology, and from those results infer the relative role of sub-surface (groundwater) hydrology on the wetland system.

The hydrological study was undertaken through the following steps:

- Literature review of hydrology in the area
- Local and expert observations
- Review of historical images of inundation
- Runoff routing modelling including gauged surface flow data
- 2D modelling of flood extent
- Conceptual hydrology models

These steps have been included as sections below describing the techniques used.

Literature review of ground and surface water hydrology in the study area

We examined publically available literature for information describing the surface water and groundwater hydrology of the area. Particular attention was paid to the interaction between surface water and groundwater including deep aquifers (springs), water-table aquifers associated with drainage lines and especially any evidence of groundwater interaction with waterways or other wetlands in the area. This information has been used to help explain the overall hydrology of the wetlands.

Local and expert observations

Discussions with local landholders (see Local Perspectives study), state water agency officers, scientists conducting wetland vegetation, terrestrial and aquatic fauna surveys, and other expert observations and insights into the hydrology of the study area were used to construct and/or qualify the models.

Analysis of historical images

Historical Landsat images were processed to identify areas of inundated non-riverine wetlands and estimate of the extent of inundated habitats at various dates. Landsat images throughout the year were selected for analysis from a typical “very wet year”, an “average rainfall year” and “very dry year”. The years selected were based on rainfall records, stream gauge data and availability of suitable cloud-free Landsat images. Following the processing of Landsat images to derive polygons of inundated habitat, the total number of inundated wetland polygons and total area (ha) of inundated wetland was calculated for each image date. These were used to examine changes in distribution and extent of wet areas under a range of seasonal and annual climate conditions.

For comparison with Queensland Government wetland mapping results for the DIWA site, extent of inundated areas was mapped following a period of good rainfall in a wet year, when all wetlands would expect to be filled. Consistent with Queensland Wetland Mapping Guidelines, only polygons of 1ha or larger were counted in mapping.

2.1 Hydrologic modelling

Simple hydrologic modelling was undertaken to estimate flood hydrographs throughout the study area for various events. RORB modelling was used for this study, which is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce the hydrograph.

The events determined to be most relevant to the objectives of the study included the 1 year, 2 year, 5 year and 10 year Average Recurrence Interval (ARI) events. Less frequent (larger magnitude) events weren't considered necessary to this study due to an understanding that the 10 year ARI events interact (through riverine flooding processes) with most of the non-riverine wetlands in the study area. The steps below outline the development of the Palm Tree Creek hydrologic model; Robinson Creek is included in this calculation as a tributary of Palm Tree Creek.

2.1.1 Stream gauging stations

An investigation of the stream gauging stations located in the Palm Tree Creek catchment was undertaken. Two stations were identified on Robinson Creek (one open, one closed) and three stations on Palm Tree Creek (one open, two closed). The length of the flow records were assessed for each station. Four of the five stations had flow data of suitable length (number of years) to be used in hydrologic investigations, including flood frequency analysis (FFA) which was to be used as the basis of calibrating the hydrologic model. These four stations are described in Table 1 Four gauging stations suitable for hydrologic investigations. The hydrologic stations and their locations in the catchment are presented in Figure 2.

Table 1 Four gauging stations suitable for hydrologic investigations.

Gauging Station ID	Name	Location	Length of record (years)	Catchment area (km^2)
130341A	Robinson Creek at Glenleigh (upper catchment)	Upper Robinson Ck	18	1,056
130375A	Robinson Creek at Broadmere	Middle Robinson Ck	6	1,597
130313A	Palm Tree Creek at La Palma	Middle Palm Tree Ck	56	2,660
130325A	Palm Tree Creek at Bloomfield	Lower Palm Tree Ck	21	3,133

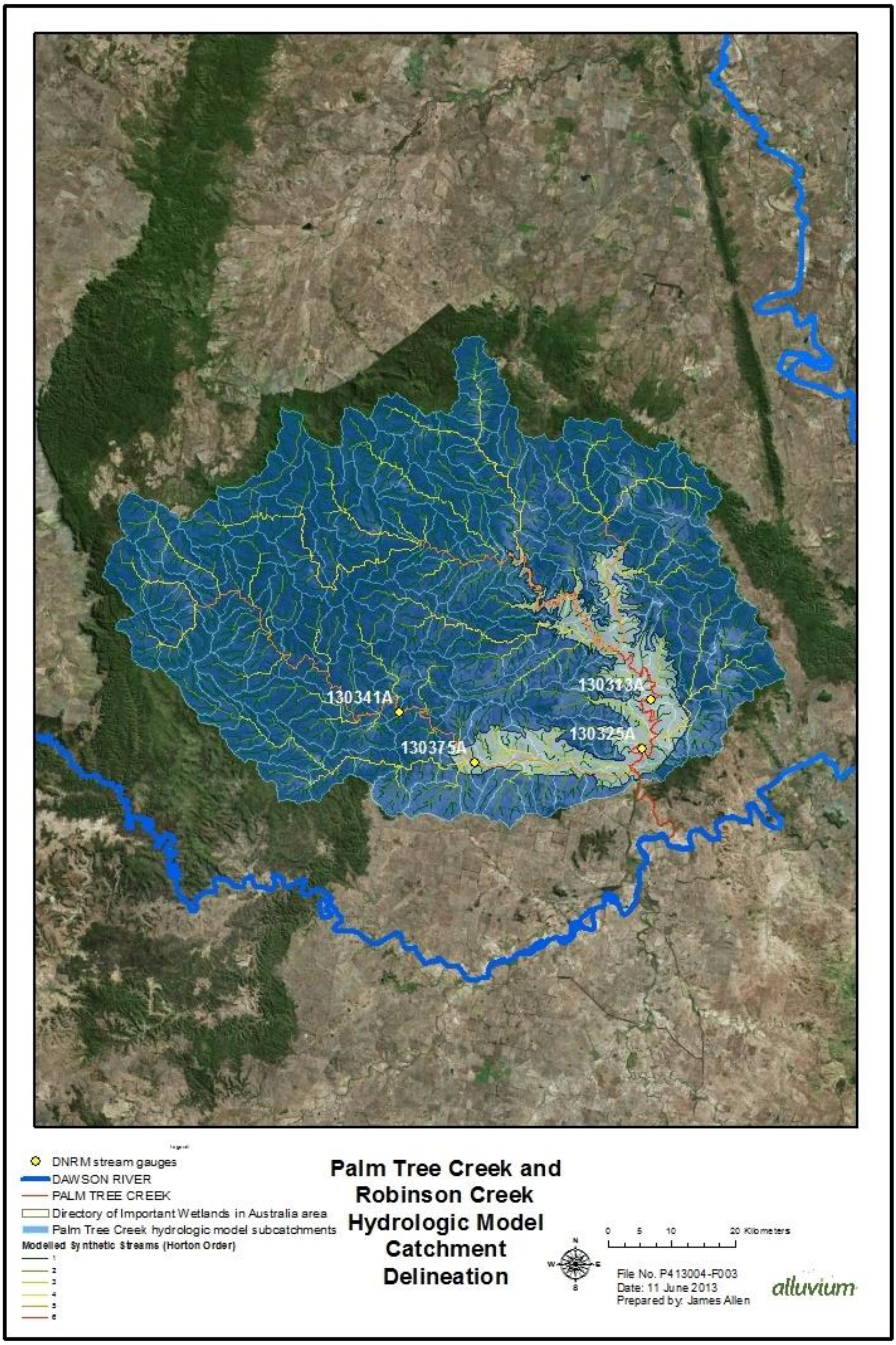

Figure 2 Palm Tree Creek and Robinson Creek hydrologic model catchment delineation and location of stream gauging stations.

2.1.2 Flood frequency analysis (FFA)

Flood frequency analysis (FFA) was undertaken on the gauged flow of the four suitable stations. Recognised industry FFA software including AQUAPAK and Flike were used to undertake the analysis. The purpose of the FFA was to develop a greater understanding of the frequency and magnitude of flow events that occur in Palm Tree Creek and Robinson Creek systems and provide a way to calibrate the hydrologic model prior to model outputs being used in the 2D model. The FFA curves for the four stream gauging stations are presented in Figure 3.

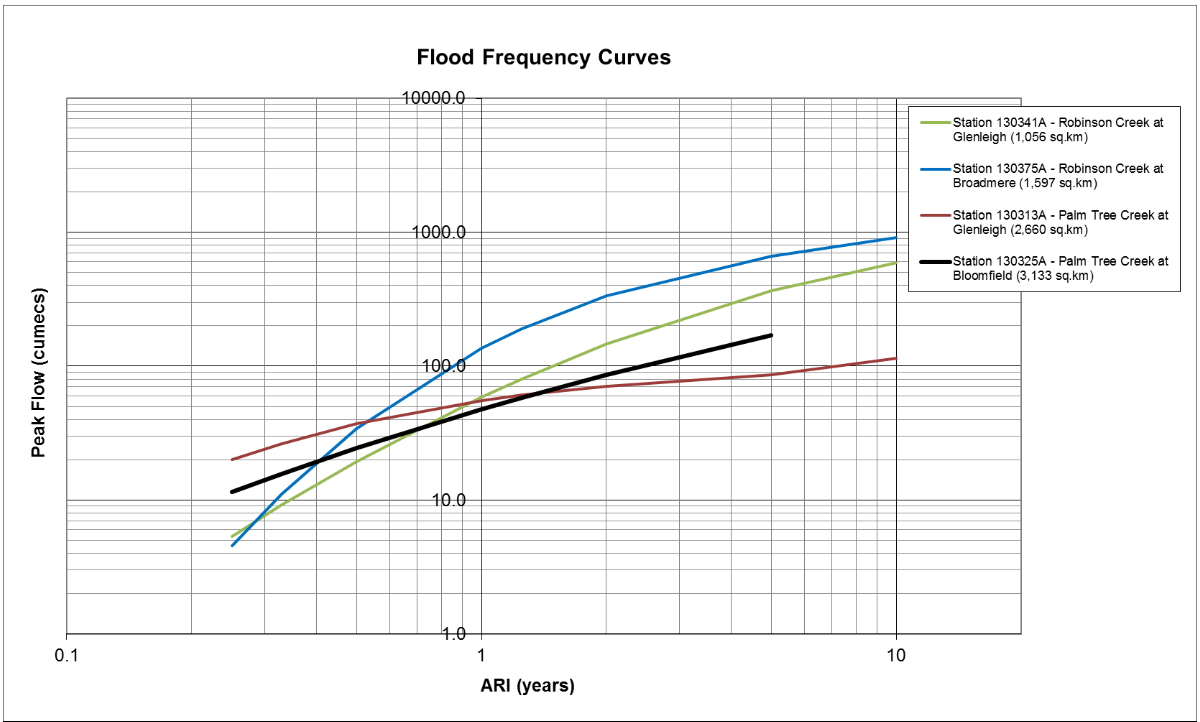

Figure 3 Flood Frequency Analysis Curves from Palm Tree Creek and Robinson Creek gauges

2.1.3 Hydrologic model

The hydrologic modelling software used in this study is RORBWin version 6.15, a Windows version of the industry accepted RORB program (Laurenson et al 2007).

A RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing the runoff through the catchment system, combining flows at channel junctions; and
- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of stream flow, and the slow response or base flow component has not been included in the model.

Setting up the model comprises:

- Determining the catchment boundary and dividing the catchment into sub-catchments;
- Calculating the area of each sub-catchment;
- Placing model nodes at sub-catchment inflows and junctions;
- Placing reach storages between nodes; and
- Measuring the length of reach between adjacent nodes.

The RORB model requires four parameters to be specified which include k_c, m, initial loss (IL) and continuing loss (CL). The k_c and m parameters are factors in the storage discharge relationship.

The storage discharge relationship for the reach storages in the model has the general form:

$$S = 3600k\,Q^m$$

Where:

S is the volume of water in storage (m^3);
k is related to travel time of a particular reach and the characteristics of the whole catchment;
Q is outflow rate from the reach storage; and
m is a dimensionless exponent representing the non-linearity of catchment response. m varies in the range 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a value of 0.8.

The relationship between k and k_c is given by the equation:

$$k = k_{ri}\,k_c$$

Where:

k_{ri} is the relative delay time of reach i; and
k_c is an empirical coefficient applicable to the catchment and is a constant for the whole catchment.

The two rainfall loss parameters of initial loss and continuing loss are used in the generation of the rainfall excess hyetograph for the model. Initial loss is the rainfall at the start of a storm event which fills soil and groundwater storage, is intercepted by vegetation, or is lost by another process and does not contribute to runoff. Continuing loss is the ongoing portion of rainfall that falls after the initial loss that does not produce surface runoff. This could be due to deep soil storage, vegetation interception or evaporation. The loss parameters used in the model can be storm and catchment specific.

2.1.4 Catchment delineation

This section outlines the process taken to delineate the hydrologic catchment for Palm Tree Creek including Robinson Creek, and the steps taken to incorporate the delineation into the RORB runoff routing model.

Catchment delineation and subdivision was undertaken using the CatchmentSIM software program, which delineates sub-catchments from a Digital Terrain Model (DTM), calculates their properties and creates output files for a range of hydrologic modelling packages including RORB.

For the hydrologic modelling, the following data source was used for generating a DTM:

- 1 arcsecond NASA SRTM 30m DEM grid tiles acquired by Alluvium on March 2013 from Geosciences Australia.

The catchment delineation and subdivision took account of all the waterways within the study area as defined by the 1:100,000 scale Topographic Data acquired from Geosciences Australia.

Following delineation of the sub-catchments, the CatchmentSIM model was exported as RORB catchment files using the CatchmentSIM-RORB macro (6.0 v3). The catchment files were then modified to specify the locations where hydrograph outputs were required for the FFA, model calibration and 2D modelling inputs.

The Palm Tree Creek hydrologic model has 149 subcatchments. The resulting layout of subcatchments and reaches (including location of gauging stations) is shown in Figure 2.

CatchmentSIM was also used in this study to estimate the catchment areas contributing runoff directly to the wetlands being assessed. See section 3.4.2.

2.1.5 Hydrologic model calibration

The RORB model was used to generate flood frequency curves at each of the four gauging station locations within the hydrologic model, using median loss parameters (initial and continuing loss) and model parameters derived from a regional relationship for Queensland (Weeks 1986) (NOTE: Parameters derived from a regional relationship are suitable when it is not possible or required to calibrate the specific study catchment. Regional relationships are generally derived from a large sample of catchments across the region of interest). The results were compared to the flood frequency curves derived through the FFA. This approach was considered appropriate because of the coarseness of the digital elevation model (DEM) available for the 2D flood model.

The comparison of all four FFA curves and RORB flood frequency curves is presented in Figure 44. While two of the FFA curves (both derived from Robinson Creek gauging stations) provided acceptably close matches to the RORB curves, the other two FFA curves (both derived from Palm Tree Creek gauging stations) seemed to substantially underestimate the magnitude of the peak flow rates estimated by the RORB model. After further investigation, the FFA results for the two Palm Tree Creek stations were excluded from the calibration due to unrepresentative rating curves for larger depths in particular and hence underestimated flow rates for deeper flows.

With the Palm Tree Creek FFA results excluded, it was considered reasonable to simply adopt the parameters derived from the regional relationship for Queensland (Weeks 1986) due to reasonable agreement between the RORB results with the two Robinson Creek gauging station FFA curves. No adjustment of model parameter based on the comparison against FFA results could be justified.

Note that more detailed hydrologic model calibration would be required if the model was to be used to estimate design flow rates for any alternative purpose.

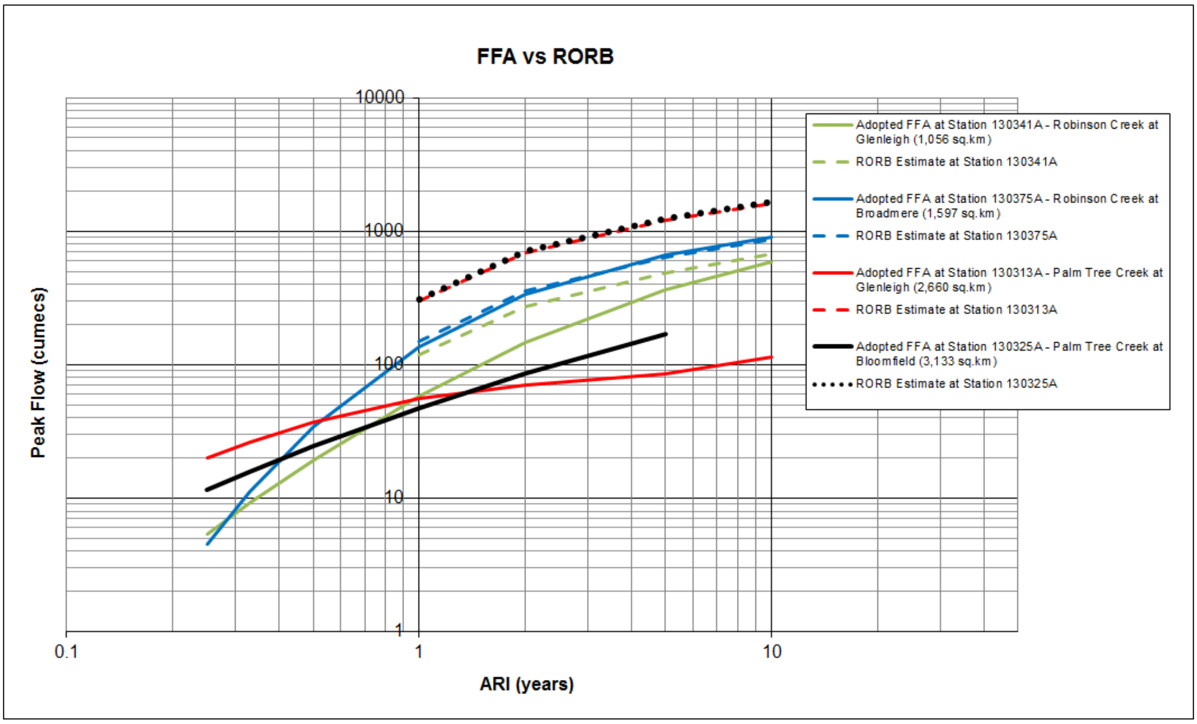

Figure 4. Gauging Station FFA versus RORB modelling results using regional parameters

2.1.6 Adopted hydrologic model parameters

Due to limited gauged data for calibration an m value of 0.8 was determined to be suitable for this study. With an m value fixed at 0.8, the kc value for the RORB model was derived from a regional relationship for Queensland (Weeks 1986). The derived value was kc = 81.07. The adopted kc and m values are listed in Table 2.

As the FFA was used to calibrate the modelled peaks, as opposed to the losses (which it is often used in hydrologic models for design flows), it was necessary to fix the losses to median values typically used for uncalibrated design models in Queensland. These values are also presented in Table 2.

Table 2. Adopted parameters for the Palm Tree Creek hydrologic model

Parameter name	Adopted number
k_c value	81.07
m value	0.80
Initial losses (IL)	25 mm
Continuing losses (CL)	2.5 mm/hr

2.2 2D flood modelling

2D flood modelling was undertaken to develop an understanding of the extent of flooding and related riverine linkages to the non-riverine wetlands in the study area under various flow events (1 year to 10 year ARI). This section outlines the development of the Palm Tree Creek and Robinson Creek 2D flood model.

Topography

The topography of the 2D model was built exclusively from NASA Shuttle Radar Topography Mission (SRTM) 1 arc second data. This data has a resolution of approximately a 30 metre grid and therefore is not highly accurate in its representation of the terrain, in particular of the watercourses. While this is not ideal, this data was the best available that covered the study area and still considered suitable to develop a model that provides a better understanding of surface water- wetlands interaction.

2D flood model set-up

The 2D flood model was built using XPSWMM, a hydrodynamic modelling software package, which couples together the SWMM 1D model and the 2D finite difference model TUFLOW.

The downstream boundary conditions for Palm Tree Creek have been setup to have minimal impact on the water surface elevations within the study area.

Figure 55 presents the 2D flood model set-up graphically and Table 3 summarises the model setup and the data used.

Model extent

The 2D modelling extent covers the entire study area defined by the Palm Tree Creek and Robinson Creek wetlands DIWA (*Directory of Important Wetlands in Australia)* area. The Palm Tree Creek and Robinson Creek 2D flood model outfall is approximately 2.6 km downstream of the Palm Tree Creek and Robinson Creek confluence and 19.3 km upstream of the Dawson River. Hydrology nodes are located on the main channels of the watercourses entering the study area from upstream. The total area of the model is 1,255 km^2.

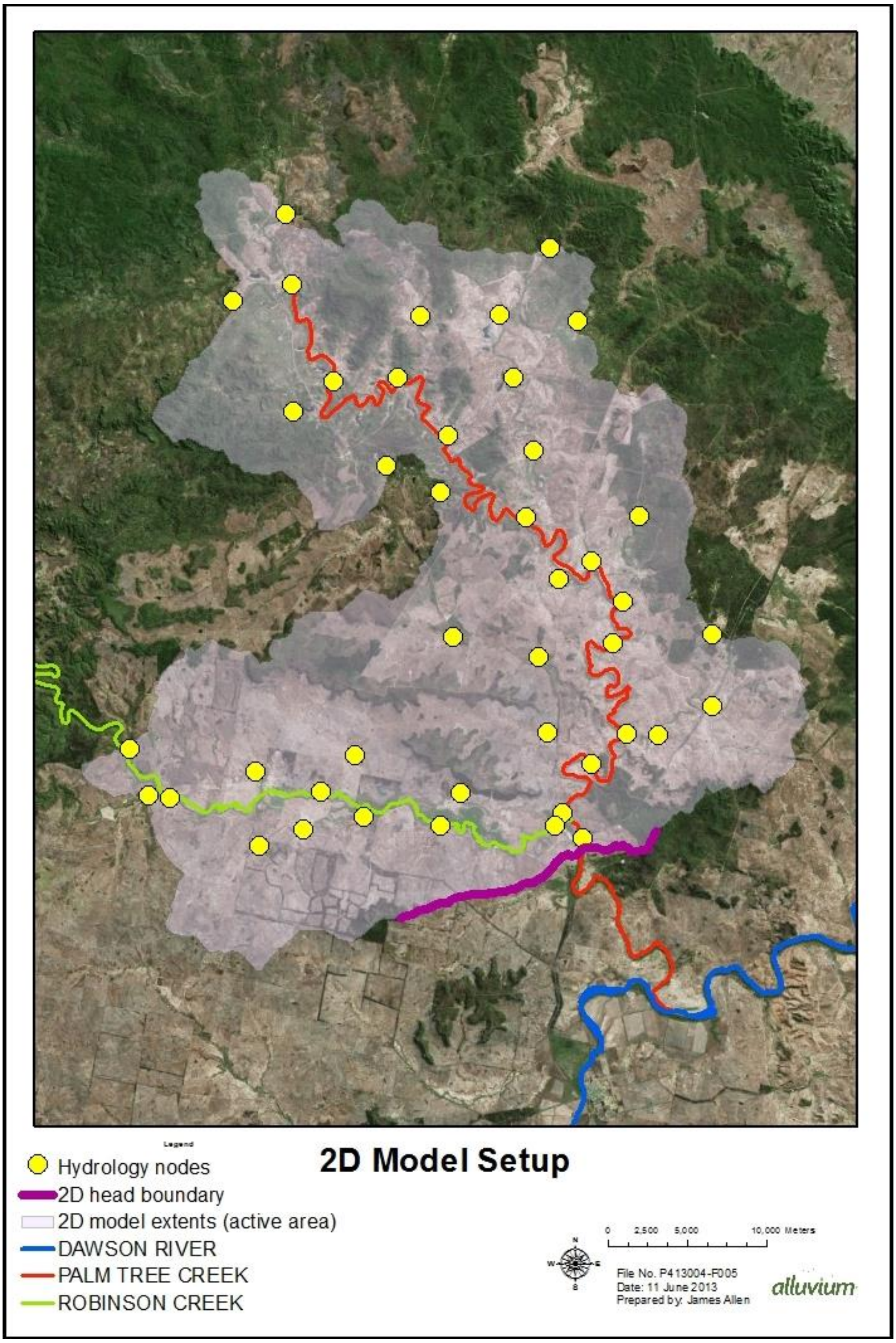

Figure 5 2D Model Setup

Table 3. Summary of model setup and data used in the Palm Tree Creek and Robinson Creek 2D flood model.

Model component	Data	Provider	Comments
2D elevations		Geosciences Australia download	Provides full coverage of 2D model area. Downloaded by Alluvium in January 2013.
Nodes		Alluvium	Located based on catchment delineation and aligned with RORB model subcatchment outlets
Catchment hydrology		Alluvium	Determined using RORB hydrologic modelling.
Aerial of study area and surrounds		Arc Map Basemaps	Provides full coverage of study area and catchment area.

Cell size

The model was configured using a fixed cell size of 30m. This was suitable given the resolution of the topographic data is approximately 30m.

Roughness

Manning's n coefficient is representative of roughness or friction applied to a flow by a channel. The Manning's n roughness coefficient for the model was set to a value of 0.01 (following model validation which tested various Manning's n values between 0.05 to 0.01). While 0.01 is considered to be a very low value for such a well-defined watercourse system the coarseness of the topographic data used required a low value to ensure peak flows were as representative as possible. For the same reason, the single Manning's n value was assigned across the whole model, since multiple Manning's n values would not improve the model's representation of the system.

Hydrology nodes

As previously mentioned, hydrologic inputs suitable for the 2D model were produced and extracted from the RORB hydrologic model for the 1 year, 2 year, 5 year and 10 year ARI events. These were output from the hydrologic model in the form of hydrographs and input into the hydrology nodes in the 2D model (results in sections 3.4 and 3.5). See Figure 5 for the location of the hydrology nodes. These hydrographs represent inputs from both the catchments external (upstream) to the study area and runoff generated in local sub-catchments.

Critical durations

The critical durations of the events modelled were determined through the RORB hydrologic model. For all four events the critical duration was estimated to be 18 hours. While other durations may be more critical in terms of flood levels and extents at various locations throughout the study area, the hydrologic model critical durations were considered to provide a suitable estimate of flood extents for this study, given the results are not to be used for design/flood protection purposes.

3 Results

Understanding the limitations in extent and quality of data available through this study, appropriate caution should be used when interpreting and using these results.

3.1 Literature review of surface and groundwater hydrology in the study area

The study area of this assessment has been defined by the Directory of Important Wetlands in Australia (DIWA) area for Palm Tree Creek and Robinson Creek wetlands. The study area is 502.2 km^2 and includes 1.9 km^2 of lacustrine wetlands, 24.1 km^2 of palustrine wetlands and 24.1 km^2 of riverine wetlands, as mapped by Queensland Government wetland mapping. In total, the site potentially supports at least 50 km^2 of aquatic habitat, most of which is subject to seasonal and flood-drought wetting cycles. The 2009 Queensland Government wetlands mapping version 3.0 indicates approximately 155 (mostly) palustrine and (few) lacustrine wetlands within the DIWA site boundary.

The study area is located in the Fitzroy Basin with Palm Tree Creek flowing directly into the Dawson River. Robinson Creek flows into Palm Tree Creek approximately 20 km upstream of the Dawson River. Robinson Creek has a catchment area of approximately 1,840 km^2 while Palm Tree Creek has a catchment area of approximately 3,230 km^2. On a catchment area basis, Palm Tree Creek has a higher density of non-riverine wetlands.

The Palm Tree Creek and Robinson Creek wetlands include floodplain lakes and non-floodplain soil lakes (DEHP, 2013). As well as lacustrine wetlands (“lakes”) which are predominantly free of emergent vegetation, the study area has both palustrine wetlands (“swamps”) and riverine (in channel) wetlands, as defined by the Queensland Wetlands Program mapping (DEHP 2013).

A number of large developments have been proposed in the region. These include coal mining (Millennium Expansion Project, The Range Project), coal seam gas (APLNG, GLNG, QGC and Arrow) and the Nathan Dam and Pipeline. Each of these proposed projects has prepared an environmental impact statement. Furthermore, a cumulative Underground Water Impact Report (UWIR) has been prepared by the Office of Groundwater Impact Assessment to address and manage potential cumulative groundwater impact on springs from all proposed coal seam gas production in the Surat Cumulative Management Area (CMA). The literature review presents a summary of information relevant to the hydrology and hydrogeology of the Palm Tree and Robinson Creek Wetlands below.

The Range Project by Stanmore Coal

The Range Project by Stanmore Coal has a project area located 80 km South-east of Taroom, and within the Surat Basin. Regional groundwater flow direction has been interpreted from available desktop based information to be in a North-westerly direction in the vicinity of The Range Project in both the Walloon Sub Group and Hutton Sandstone. This is in the direction of the Dawson River and the Palm Tree Creek catchment (Stanmore Coal Range Project, 2012).

The Range Project report (2012) also states that:

"Aquatic ecosystem environmental values are more typical of surface water. Groundwater could have aquatic ecosystem values where there is a connection to surface water via either baseflow to streams or springs. Groundwater in the Project area is not known to provide baseflow to any of the streams. Recharge springs are known to occur some 50 km north of the Project site, associated with Precipice Sandstone outcrop."

Hydro-geologic investigation would be required to determine if aquifers in the Walloon Sub Group, Hutton Sandstone and Precipice Sandstone have connection to any other aquifers beneath the study area and to the surface water bodies and wetlands of the DIWA site.

Millennium Expansion Project

The Millennium Expansion Project is located in the Isaac River catchment in the northern Fitzroy Basin while our study area is located in the Dawson River catchment – part of the southern Fitzroy Basin. The water resources chapter of the Environmental Impact Statement for the Millennium Expansion Project (Peabody, 2010) reports on a number of relevant findings. Groundwater dependent ecosystems may develop where springs and permanent water bodies, such as lacustrine wetlands, are connected to aquifers. Such aquifers may include quaternary alluvial aquifers systems (Peabody, 2010). The literature review for the present study area has not confirmed the presence of quaternary alluvial aquifer systems, and further work is recommended to improve understanding of alluvial (as well as artesian) groundwater resources, behaviours and influence in the Palm Tree Creek and Robinson Creek catchments.

A suitable method of determining the possible hydrologic influence of groundwater on the study area wetlands would be to approach assessment from a water quality perspective. If water quality of the wetlands exceeds aquatic ecosystem guideline levels parameters such as salinity, arsenic, chromium, copper, manganese and zinc, it may be concluded that there is significant groundwater interaction (Barnett et al 2012). This may also be evidenced by the condition of the wetlands. Comparison of ground water sample quality analysis to wetland water quality analysis would ultimately provide the best indication of groundwater-surface water interaction.

Australia Pacific LNG Project

The Australia Pacific LNG Project development areas are mostly located more than 100 km from the study area. However, a numerical groundwater model is presented in the Ground Water chapter of the project report (Australia Pacific LNG Project EIS, 2010), and the domain of that report also covers the full extent of the current study area. While the report made no mention of the Palm Tree Creek and Robinson Creek catchments, it stated that "numerous high value recharge and discharge spring complexes, associated with the Hutton Sandstone and Precipice Sandstone units, also occur in proximity to the Taroom and Injune townships, outside the Project's development areas (DNR 2005). The discharge spring complexes located near the Taroom township are supplied by artesian flow from the Precipice Sandstone, rising to the surface through joints and fractures in that unit. These complexes are known locally as 'boggomosses' (GABCC 2000), and provide a wetland habitat in a region that experiences prolonged drought conditions."

These pieces of evidence reinforce the need for further hydro-geologic investigations into groundwater discharge in the study area, with a focus on potential links with the Hutton Sandstone as well as the Eurombah formations. Further surveys in the Palm Tree Creek catchment could potentially identify similar aquifer and spring resources.

Nathan Dam and Pipeline EIS

The Nathan Dam and Pipeline EIS (SunWater, 2011) identified two Fensham Great Artesian Basin (GAB) spring sites (Fensham and Fairfax, 2008) just downstream of the study area; one in the Palm Tree Creek catchment and the other in the Dawson River catchment just upstream of Palm Tree Creek – Dawson River confluence. These springs are located in the footprint of what has been defined as the "Artesian Area" which the extent of Palm Tree Creek on the map also sits within (presumably Robinson Creek does too although it is beyond the extent of the mapping). The springs identified in this study were from the Queensland Springs Database which includes springs identified by Fensham and Wilson (1997) and Fensham and Fairfax (2005). An update of the Queensland Springs database version 5 (Fensham and Fairfax, 2008) can be found at http://www.nrm.qld.gov.au/services_resources/item_details.php?item_id=33188.

A recent data download from Queensland Springs Database showed no springs associated with wetlands in the Palm Tree Creek and Robinson Creek wetlands study area. Nevertheless, the two Great Artesian Basin (GAB) recharge area springs confirmed just downstream of the study area (see above) indicate potential for future discovery of groundwater dependant systems in the Palm Tree Creek and Robinson Creek catchment.

Field investigations undertaken as part of the Nathan Dam and Pipeline EIS (SunWater, 2011) identified an additional 17 springs within the Nathan Dam and Pipeline project area, just downstream of the Palm tree Creek and Robinson Creek catchment (Chenoweth, 2010).

A Department of Natural Resources (DNR) review of the Boggomoss springs in the Dawson River (Resource Sciences Centre, 1996) noted that of the springs surveyed, all were associated with discharge from the Precipice Sandstone except for a series of springs located in the Palm [Tree] Creek area approximately 10 km north north-west of Taroom. These springs were believed to be associated with groundwater discharge from the Hutton Sandstone / Eurombah Formation (SunWater, 2011).

A case study called "On the ground: Fencing wetlands near Taroom" produced by the Fitzroy Basin Association (FBA) as part of their Land and Water Series did not discuss anything in relation to groundwater interactions with wetlands, however it quoted an important point made by a landholder in relation to the hydrology of wetlands, which stated simply that "The stability of the natural levees determines how much water stays in your wetlands."

3.2 Local observations

Observations and perceptions gathered from local interviewees (obtained via the Local Perspectives study, Alluvium 2013) help to qualify and verify the hydrological models and augment the overall understanding of hydrology for these wetlands.

General observations about Palm Tree Creek and Robinson Creek system:

When first encountered by Ludwig Leichhardt in 1844, the general nature of the two watercourses included the following (Rechner 2003):

a) Palm Tree Creek was a broad sandy creek, and
b) Robinson Creek, adjacent to Lake Murphy, had a deep channel and a vegetated sandy bed.

On the same exploration in 1844 John Gilbert noted that Palm Tree Creek had the greatest number of lakes and dense reed-beds on each side of the creek, and understood it to be valuable as a summer run (from Rechner 2003). At the time of the present study (2013) Palm Tree Creek still supports the greatest number of non-riverine wetlands.

Most of the interviews that took place for the Local Perspectives study (Alluvium 2013) were of landholders who have lived along Robinson Creek. Only two landholders provided information on Palm Tree Creek and its wetlands, both of which were for the La Palma property and associated La Palma lagoons. Given the extent of the system it should be recognised that at best, this information will only provide an indicative understanding the hydrology of the wetlands in the system, especially for the Palm Tree Creek wetlands.

NOTE: The following statements were from a combination of interviewee's personal records and memories, but have not been checked for accuracy. Explanations for the reported phenomena may be more complex than may appear necessary when based only on the face value of the interviewees' comments. Thus the information on dates and periods, etc, should be interpreted with appropriate caution.

Local observations about floods, droughts, wet and dry periods, etc:

Robinson Creek wetlands

a) Not a lot of dry times although Robinson Creek can be dry for years at a time.
b) Nine Mile Swamp (Verbena Park) only seen really full about 3 times since 1954.
c) Prior to 1981 (not sure over what period) previous owners had only seen the Lake Waunui dry twice before. Could dry up for years though.
d) Dry to wet times cycles every 10 years on average.
e) Flash floods could occur that cut off access for droving cattle to sales yards.
f) Dawson River ran backwards for about 8 hours from Palm Tree and Robinson Creek flood.
g) Flood peaks travelling from Glenhaughton (upper catchment) to Taroom seem to have sped up from 36 hours to 24 hours.

h) Milky Swamp (Broadmere) loses approximately 6 foot of water to evaporation each year. Still takes about 2 years to completely dry out after filling.
i) Time of concentration from the top of the catchment could be around a week to 2 weeks in Palm Tree Creek and 2 days in Robinson Creek.

Palm Tree Creek wetlands

a) On average the wetlands had water in them for 2 years, filling via floods. If there are no floods for 2 or 3 years they dry out.
b) La Palma swamps (on lower Palm Tree Ck) generally top up every year and stay full for years (about two) but would dry out along with the creek every 10 years or so. They don't completely fill every year.
c) Box Tree swamp takes nothing to fill and Belle Eau fills only 10-12 years because of high creek banks.
d) Could get days of notice about a flood coming from the top of the catchment. Could be around a week to 2 weeks in Palm Tree Creek and 2 days in Robinson Creek.
e) Creek could flood quickly too – half way up the bank from morning to afternoon with the right storm.
f) Palm Tree Creek once ran for about 9 months of the year (which year?).

Timeline

a) Big flood of 1928 which came through the La Palma homestead leaving everything covered in mud. (Palm Tree Creek)
b) Since 1939 Lake Nunbank had been permanently full for a period of seven years and dry for a period of 5 years. (Robinson Creek)
c) 1946 saw drought (Robinson Creek)
d) Drought broke Jan/Feb 1947 (Robinson Creek)
e) 1948/49 and 51 were dry years (Robinson Creek)
f) Lake Nunbank was full in 1955 (Robinson Creek)
g) 1956 flood cut off Verbena Park from town for 3 months. (Robinson Creek)
h) 1956 flood in Dawson River lapped the floorboards of the house in Taroom.
i) 1955/56 was a big flood. (Palm Tree Creek)
j) 1962/63 the swamp came right up to in front of the La Palma house.(Palm Tree Creek)
k) 1970 and 1971 and 1983 there were big floods.
l) 1983 big flood (Robinson Creek). Had been dry since at least 1981. Ran almost constantly for a 4 – 5 years after. 1983 was a very wet year.
m) 1983 big flood went through the old (La Palma) house. Started raining Anzac Day and didn't stop for 6 months. (Palm Tree Creek).
n) 1989 (Waunui) swamp topped up again and took a couple of years to dry out. Was dry for about 15 years after.
o) 2001 Broadmere's Milky Swamp was dry for about 10 years from about 2001-2011 but came back to life overnight (Robinson Creek).

p) From the early 90's they had been dry for between 10 to 20 years. This is the longest period of time they have been observed to be dry (since 1935). (Palm Tree Creek)
q) Drought from 1990 to early 2000's with swamps dry. (Palm Tree Creek)
r) 1998 flood was big on Palm Tree Creek.
s) Big floods in 2010 and 2011. Much greater floods than previous they had seen. Flows at picnic site were deep and strong enough to move a heavy concrete table 30 yards. 2011 flood was so large that 3-4 foot higher levels occurred on the western side of the creek.
t) 2011 flood was similar to 1956. People stranded on house roof at the top of Robinson Creek. Whole region was inundated.
u) Past few years of good rainfall. Milky Swamp and countryside is currently in the best condition due to good rains of the past few years. (Robinson Creek)
v) Swamps haven't dried out for about 8 years in recent years.(Palm Tree Creek)

Groundwater

a) Sand pumping in bed of Robinson Creek when lack of water in wetlands. (Nunbank – Robinson Creek)
b) House up off the floodplain in Brigalow country had a bore drilled in 1960 that was 1,222 feet deep. (Nunbank – Robinson Creek)
c) Alluvial flat was full of water when drilled. (Nunbank – Robinson Creek)
d) Bore was sunk in 1949 at Bottle Tree property near Bimbadeen (Robinson Creek)
e) Cattle have plenty of bore water which they prefer to drink. (Waunui – Robinson Creek)
f) Cattle preferred bore water (Broadmere – Robinson Creek)
g) Groundwater is important to the agricultural industry in the region.
h) As mentioned, Palm Tree Creek ran for 9 months of the year. There was baseflow in the creek when it was dry at about elbow deep. (Palm Tree Creek)
i) No significant groundwater feeding at Lake Waunui (on Robinson Creek)
j) During drilling for irrigation water 90 feet of alluvium was found (Nunbank, Robinson Creek)

Wetland Filling Mechanisms

a) Wetlands are teardrop shapes with marshy, reedy tails where the water feeds into them.
a) Robinson Creek is a 'whole mess of flood channels and anabranches'.
b) Robinson Creek runs between Lake Nunbank, Lake Murphy and Verbena Park Lake (Nine Mile Swamp) which are all engaged as part of the floodplain. Many channels connecting Robison Creek to the lakes.
c) Nine Mile Swamp is connected to Robinson Creek via the Nine Mile Gully through creek overflows which occur usually when the creek is three-quarters full. (Verbena Park – Robinson Creek)
d) Robinson Creek fills Lake Waunui (Waunui Swamp). Not much catchment runoff (either does Lake Murphy). No groundwater feeding it. Once creek is ¾ of bank full it flows via a gully to fill the swamp which is the same flow path that Lake Murphy fills through. Flood runner is shallow enough in areas to drive over but, if wet, a car can get bogged very deeply.
e) Lake Murphy has an anabranch that drains it.

f) Too much debris (possibly indicating substantial flows bringing it in) in the Lake Waunui to run speed boat although Robinson Creek was deep enough. Sail boat was used on the swamp.
g) Milky Swamp gets water in it most years from catchment runoff. (Broadmere, Robinson Creek)
h) Other swamps on the other (North) side of Robinson Creek to Milky Swamp fill from overbank flows but only in major floods. (Broadmere – Robinson Creek)
a) Gullies run between the La Palma lagoons and Palm Tree Creek.
b) The La Palma wetlands are filled by water backing out of Palm Tree Creek. Palm Tree Creek flows don’t go through the wetlands directly. Fills through a gully flat and has to rise over a silted off area to get into the wetland.
c) La Palma wetland was connected to the creek by a major gully and another channel. Usually filling via the gully and draining by the channel but could switch with different events.

Siltation and Geomorphic Changes

a) Following a dry period of 12 month cracks appears in the bed of Lake Nunbank of five to six feet deep (Robinson Creek)
b) Wetlands along Robinson Creek have changed over the years, generally getting bigger and shallower due to sediment “silting up the outlets”.
c) During drilling for irrigation water 90 feet of alluvium was found. (Nunbank, Robinson Creek)
d) Wetlands changed from flood to flood. Over time sand filled many of the old fishing holes but the fishing is still good in many places today especially after flood. (Robinson Creek)
e) Robinson Creek is shallow now due to siltation.
f) Deep water hole on Palm Tree Creek (Lloydies Corner – Palm Vista) is all silted up. This is a common and major change seen in the creeks over the years.
g) Robinson Creek has sandy beaches on its bends.
h) Sand has become much muddier since 1981. (Lake Waunui – Robinson Creek)
i) Lake Murphy has got larger in area as evidenced by the location of dead tree rings that would have been on dry ground.
j) La Palma lagoons are expanding in size and getting shallower from the sediment contributed from each flood. (Palm Tree Creek)
k) Flat areas appear to be building up and reducing the connections between the Palm Tree Creek and the La Palma lagoons. Flood water brings in the mud/sediment which settles in the lagoons.
l) More silting of La Palma lagoon entrances and water has become shallower. (Palm Tree Creek)
m) Fishing was good along Palm Tree Creek. Fishing holes are filled with sand and silt now.

Observations for Individual Wetlands

Lake Nunbank (Robinson Creek)

Adam and Dot Clark have lived near Lake Nunbank (on Robinson Creek) since 1939. Tom and Patsy Poole lived at the Clark's property, Nunbank from 1948 to 1960. Some of the details they shared include:

a) When full, Lake Nunbank covered around 1,000 acres; 600 acres of open water and 400 acres of reeds and mud.
b) Lake Nunbank was deep enough for swimming and using a canoe on.
c) Estimated from photo that the Lake is approximately 500m from homestead in 1954.

Verbena Park Lake/Nine Mile Swamp (Robinson Creek)

The Kerlin family moved to Verbena Park in 1954. Some of the details they shared about their wetlands include:

a) Property contains a few wetlands including one known as Nine Mile Swamp. Other swamps include horse paddock swamp and sheep paddock swamp. Latter was artificial but has since been reconnected to the creek.
b) Nine Mile Swamp was rarely dry, but shallow around the edges and 8 feet deep in the middle.
c) Only seen really full about 3 times.
d) Fishing and water skiing (when really full) used to occur on the swamp. Didn't swim because of leeches.
e) House was about 100 metres uphill from the swamp when it was full.

Lake Waunui (Robinson Creek)

Malcolm and Ann McIntyre moved to Waunui on Robinson Creek in 1981. Some of the details they shared about Waunui Swamp include:

a) Before 1981 previous owners had only seen the swamp dry twice before.
b) Swamp topped up again in 1989 and took a couple of years to dry out. Was dry for about 15 years after.
c) Waunui Swamp is around 300 acres and can fill overnight. Shallower than Lake Murphy. Lake Murphy is 1,000 acres.
d) Lake Murphy is in sight of Waunui property/swamp.
e) Too much debris in the swamp to run speed boat although creek was deep enough for it. Sail boat was used on the swamp.
f) Depth of 2010 flood approximately 1.5m up shed on property.
g) Another flood got to a height of about 4m at the same shed.

Milky Swamp (Robinson Creek)

Ian Williams and wife Ros live on Broadmere property through which Sandstone Creek, a tributary of Robinson Creek, flows. Milky Swamp is the larger of a cluster of wetlands on Sandstone Creek. Over a period of more than forty years, some of their observations at Milky Swamp included:

a) Milky Swamp gets water in it most years from local sub-catchment runoff.
b) About 2 metres deep when full. About 1m deep at the time of the interview in 2013.
c) Was dry for about 10 years from about 2001-2011 but came back to life “overnight”.
d) Could canoe in the swamp and used a little sailing boat on it too.
e) When full it is about two metres deep and 7 km around.
f) No recollection of fishing in the swamp. Sandstone Creek had big waterholes and good fishing.

La Palma lagoons (Palm Tree Creek)

Born in 1935, Elgin Hay grew up on and has lived most of his adult life with wife Ineke on the “La Palma” property. John Hay grew up on La Palma property on Palm Tree Creek. Some of the observations for La Palma Lagoons (on Palm Tree Creek catchment) include:

a) On average the wetlands had water in them for 2 years, filling via floods. If there are no floods from 2 or 3 years they dry out.
b) From the early 90’s they had been dry for between 10 to 20 years. This is the longest period of time they have been observed to be dry (since 1935).
c) At least 1.5m deep based on cattle swimming with just their heads out of water.
d) Lagoon can fill overnight.
e) Other Palm Tree Creek wetlands are Box Tree swamp which takes nothing to fill and Belle Eau wetlands which fills only 10-12 years because of high creek banks.
f) Swamp stayed full for years (about two) but would dry out along with the creek every 10 years or so.
g) Photo (from early 1960s) shows homestead is approximately 300m from swamp

3.3 Analysis of historical images

Analyses of historical Landsat images enabled insights to the distribution, extent and behaviour (seasonal and long-term changes) of wetlands and hydrology in the Palm Tree Creek and Robinson Creek catchments. These are described below. Statistics on wetland numbers and area should be treated with due caution, given the range of potential errors associated with analyses of Landsat image data (eg, pixel resolution, cloud cover, weak reflectance signatures of shallow water, and effects of emergent vegetation) and absence of ground truth calibrations in this study.

Palm Tree Creek sub-catchment supports at least 134 wetlands (mapped as 1ha or larger), mostly of small to medium size. Approximately 50 wetlands in the Palm Tree Creek sub-catchment are at least 10ha in size, and only 5 of these are greater than 50ha in area. The Robinson Creek sub-catchment only supports around 20 individual wetlands, but 7 of these are relatively large (ranging between 50ha and 290ha) in area.

Queensland government wetland mapping (which only considered wetlands 1ha or larger) recorded a total 154 wetlands of 1ha minimum size (Figure 6). Our analysis of Landsat images from a very wet year (2010-2011) identified at least 160 individual polygons of inundated wetland in the Palm Tree Creek and Robinson Creek DIWA (*Directory of Important Wetlands in Australia*) boundary (Figure 6). These minor differences in total numbers of wetlands mapped may arise through mapping errors that lead to differences in the distinction of wetlands <1ha or >1ha in size. Some small wetlands detected in Landsat image analyses may at times appear as discrete wetlands and in other circumstances appear linked to other wetlands.

Queensland Government wetland mapping data indicates a total 2,527ha of non-riverine (lacustrine and palustrine) wetland. From our Landsat image analyses, the total area of inundated wetland habitat averaged approximately 3,400ha during an above-average rainfall period, 2010-2011 (Figure 9), but reached around 4000ha on several occasions. A rainfall event in December 2010 (potentially up to a 5 year ARI event) resulted in approximately 9,000ha of inundated habitat (Figure 9), however much of this area may include riparian or floodplain habitat above the level of normal wetland extent, with flood waters only partially receded at the time of the satellite image.

The total area of inundated wetland habitat in an average rainfall period (1989-1990), from 12 useable Landsat images, averaged approximately 1,700ha (Figure 7, Figure 1010). Late dry season extent of inundated (wet) area may decline to around 1000ha across the site during "average" rainfall years (Figure 10).

During very dry years, total wet areas may only range between a few tens of hectares to around 150ha (e.g.1993, Figure 88 and Figure 1111).

Wetland area responds strongly to changes in rainfall, and usually displays maximum extents during summer monsoon months (November to March), but can extend into autumn (up to April). Peaks in wetland extent have also occurred in winter months in some recent above-average rainfall years (eg, 2011, Figure 1010).

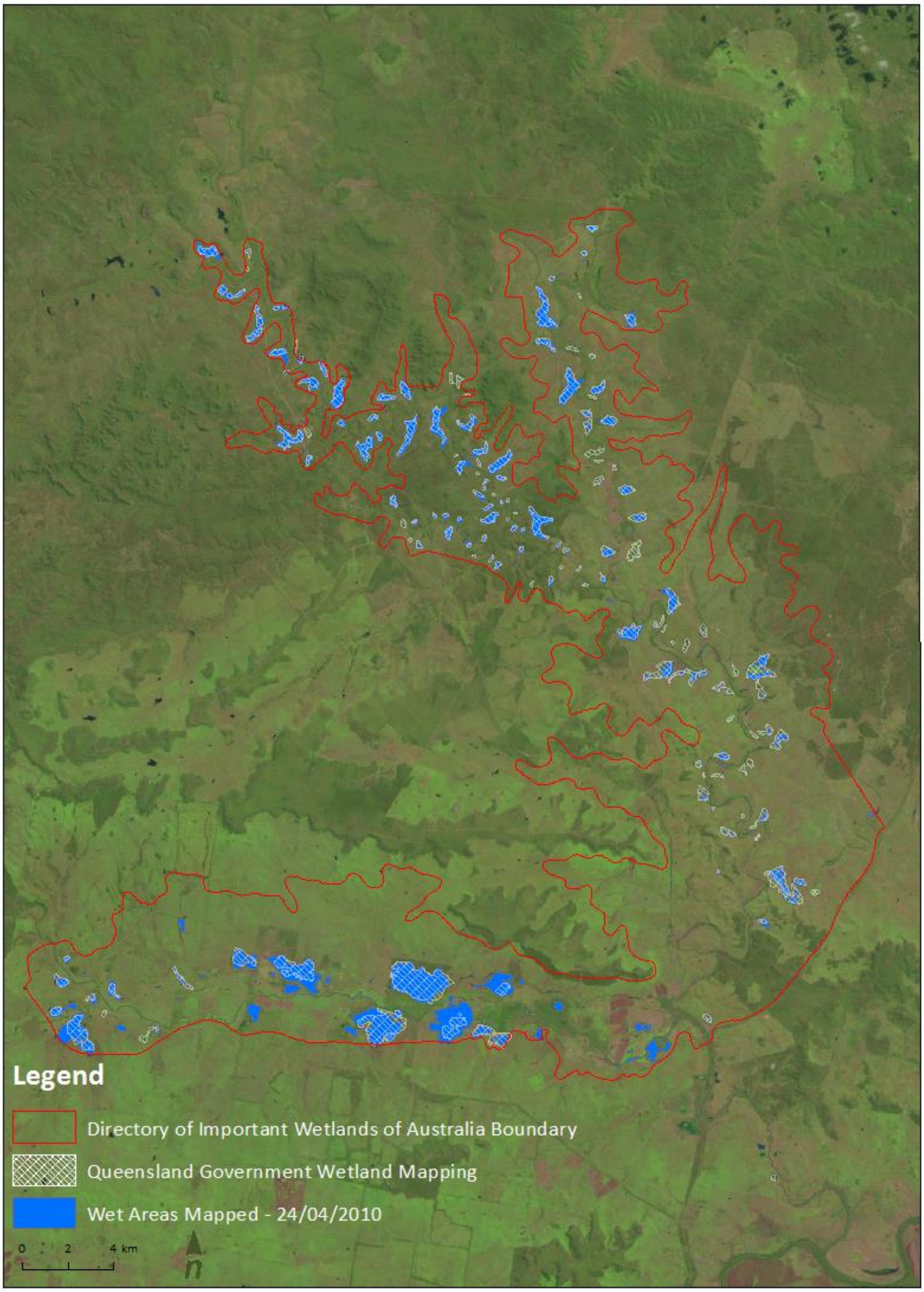

Figure 6 Landsat image analysis of inundated wetland habitat (April 2010) during an "above-average" rainfall year, plus overlay of Queensland government wetland mapping results (from WetlandInfo).

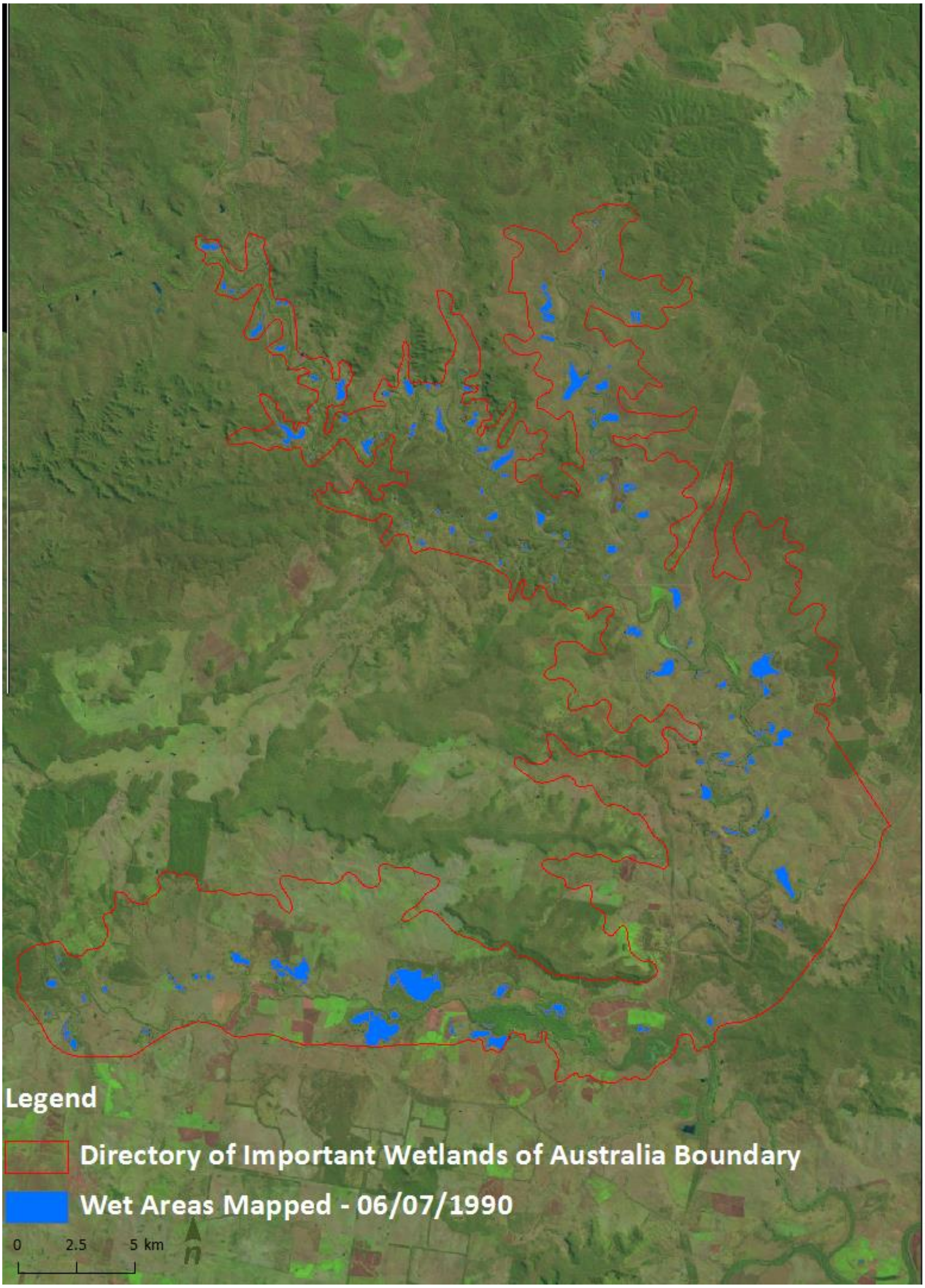

Figure 7 Landsat image analysis of wet (inundated) wetlands, July 1990 – an "average" rainfall year.

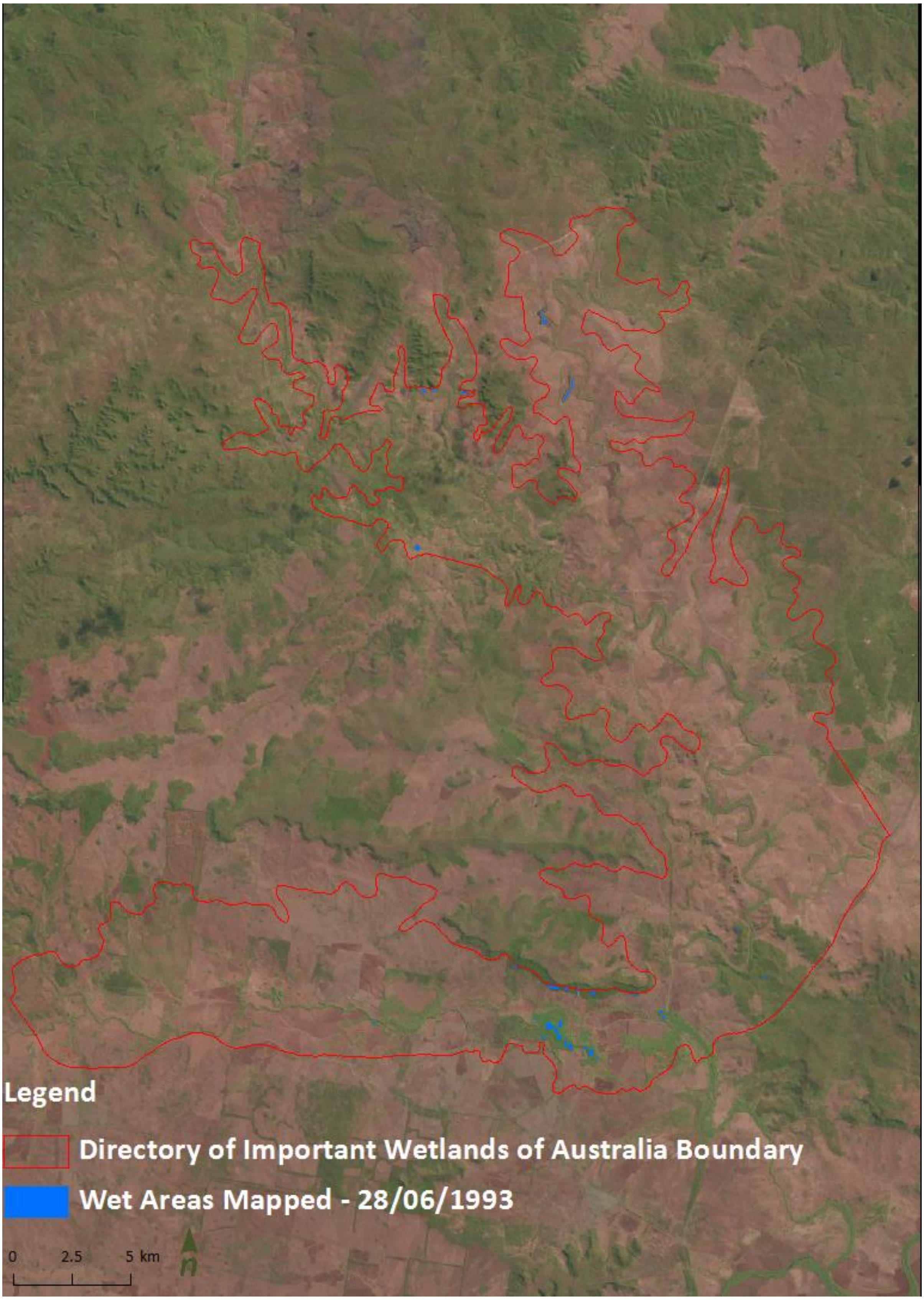

Figure 8 Landsat image analysis of wet (inundated) wetlands, June 1993 - a "very dry year".

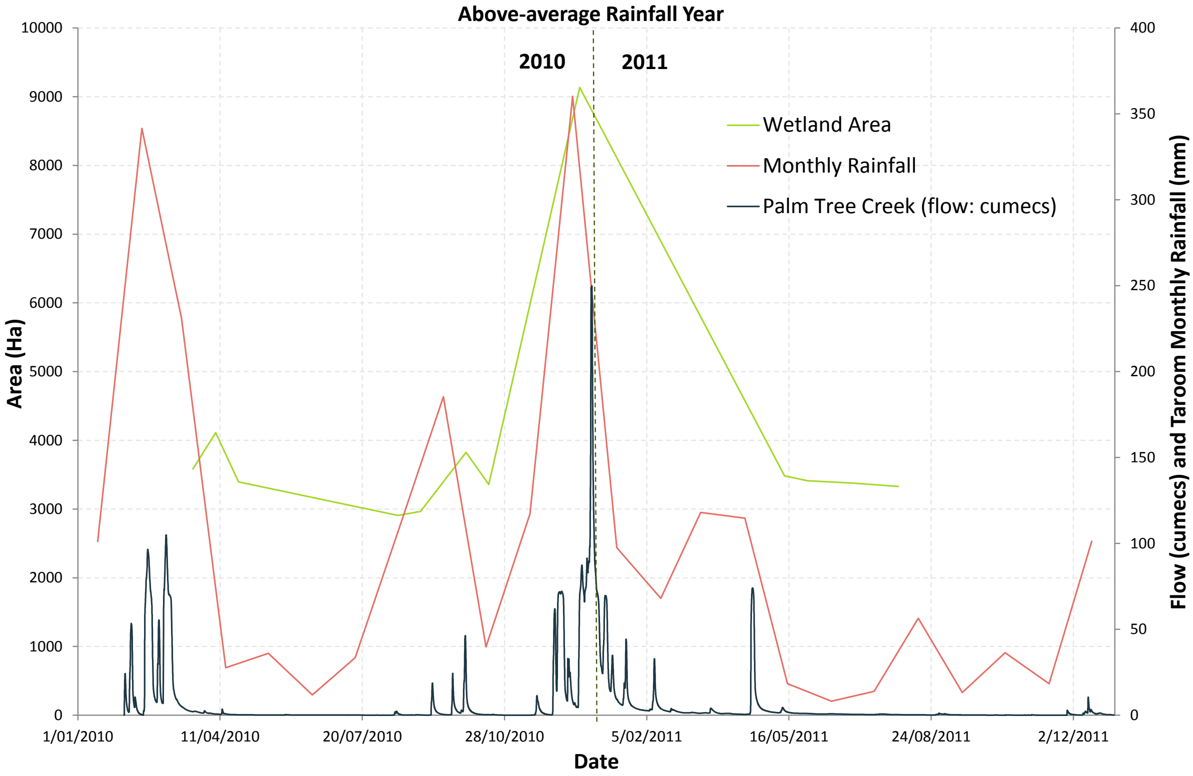

Figure 9 Estimates of wet (inundated) areas during 2010/2011 – a "very wet year".

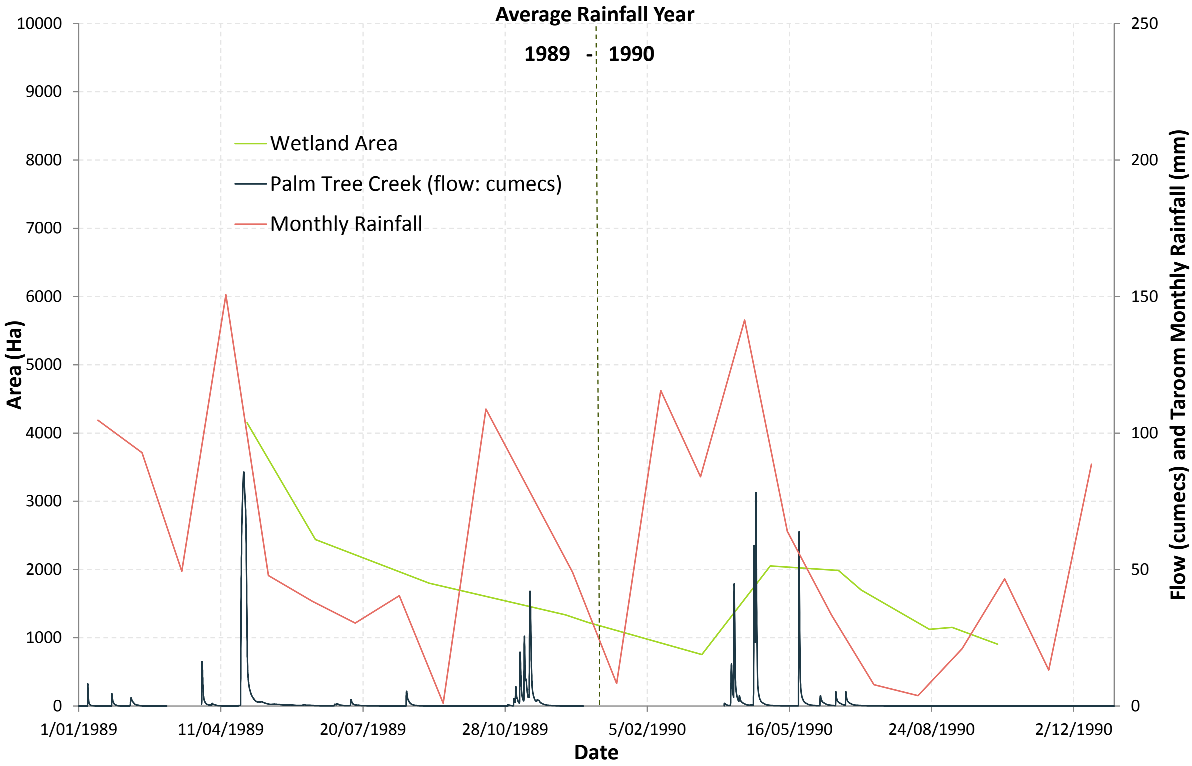

Figure 10 Estimates of wet (inundated) area during 1989/1990 – an "average rainfall year".

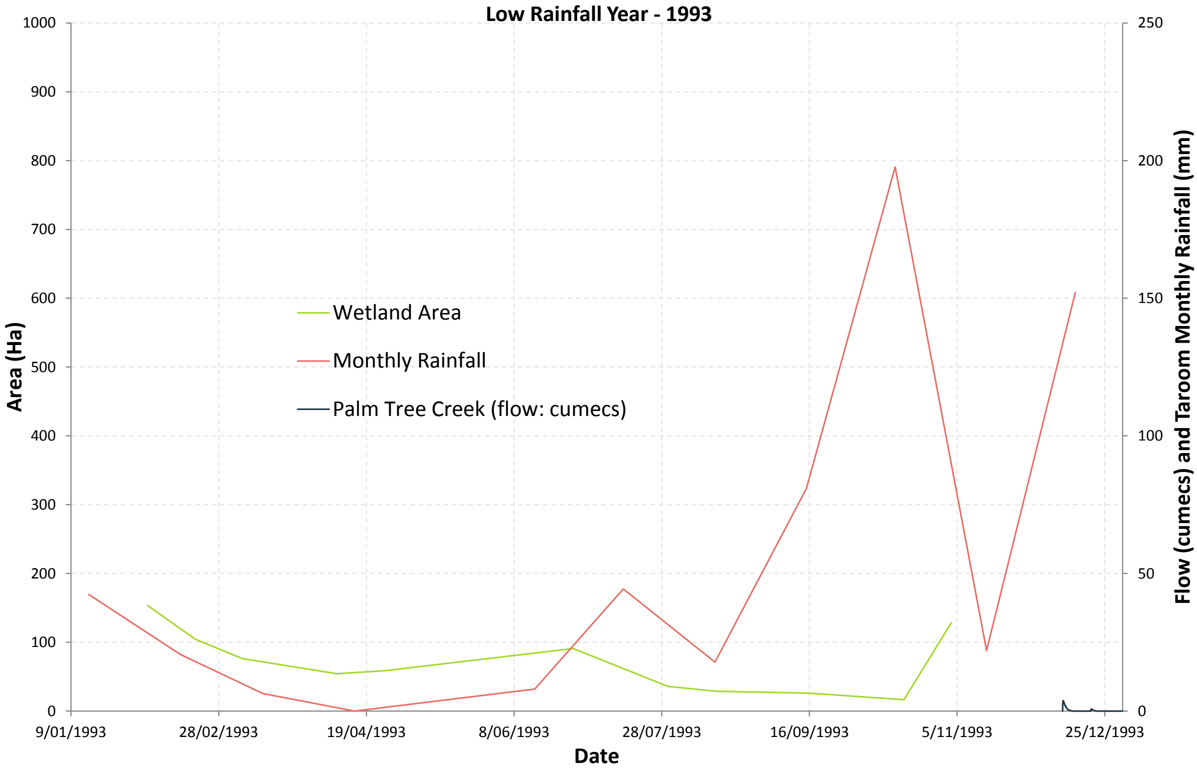

Figure 11 Estimates of wet (inundated) area during 1993 – a "very dry" year.

3.4 Hydrologic modelling

This section presents the peak discharges estimated in the flood frequency analysis (FFA) and the critical duration peak discharges estimated from the RORB hydrologic model at the four gauging station locations for all four design storm events of interest (1, 2, 5 and 10 year ARI).

Results of additional catchment delineation analysis have also been presented to show the estimated catchment areas contributing runoff directly to each of the study wetlands i.e. non-riverine flow/flood contributions to wetland filling.

3.4.1 RORB modelling and FFA results

Table 4 presents the critical duration peak discharges for the four design events of interest estimated using the RORB model as well as the FFA estimated peak flow results from the two gauging stations (both on Robinson Creek) for which the gauged data was considered reliable.

Table 4. RORB modelling critical duration peak FFA results at the 4 gauging stations for the 4 events

ARI	Gauge 130313A – Palm Tree Creek at La Palma (m^3/s)		Gauge 130325A – Palm Tree Creek at Bloomfield (m^3/s)		Gauge 130341A – Robinson Creek at Glenleigh (m^3/s)		Gauge 130375A – Robinson Creek at Broadmere (m^3/s)	
	RORB	FFA	RORB	FFA	RORB	FFA	RORB	FFA
1	300	Unreliable gauged data	307	Unreliable gauged data	118	59	151	137
2	681		704		273	146	354	335
5	1190		1240		486	366	634	661
10	1600		1680		672	589	873	910

The two Palm Tree Creek locations modelled peak discharges larger than the Robinson Creek locations. The larger contributing catchment area for the Palm Tree Creek gauges explains much of this difference.

3.4.2 Wetland catchments

CatchmentSIM was also used in this study to estimate the catchment areas contributing runoff directly to the wetlands. Coloured points representing the different local sub-catchment sizes contributing to each of the studied wetlands have been presented on Figure 12 below. Table 7 in the Appendix presents the local catchment areas for each wetland assessed in this study.

This shows that, for the wetlands studied, there are no substantial differences between Robinson Creek catchment and Palm Tree Creek catchment in regard to area of local feeder catchments for individual wetlands. Palm Tree Creek catchment appears to have a larger proportion of wetlands fed by mid-sized (200-1000 ha) local catchments than Robinson Creek catchment, but this might only be a reflection of the limited number of wetlands studied, particularly in Robinson Creek.

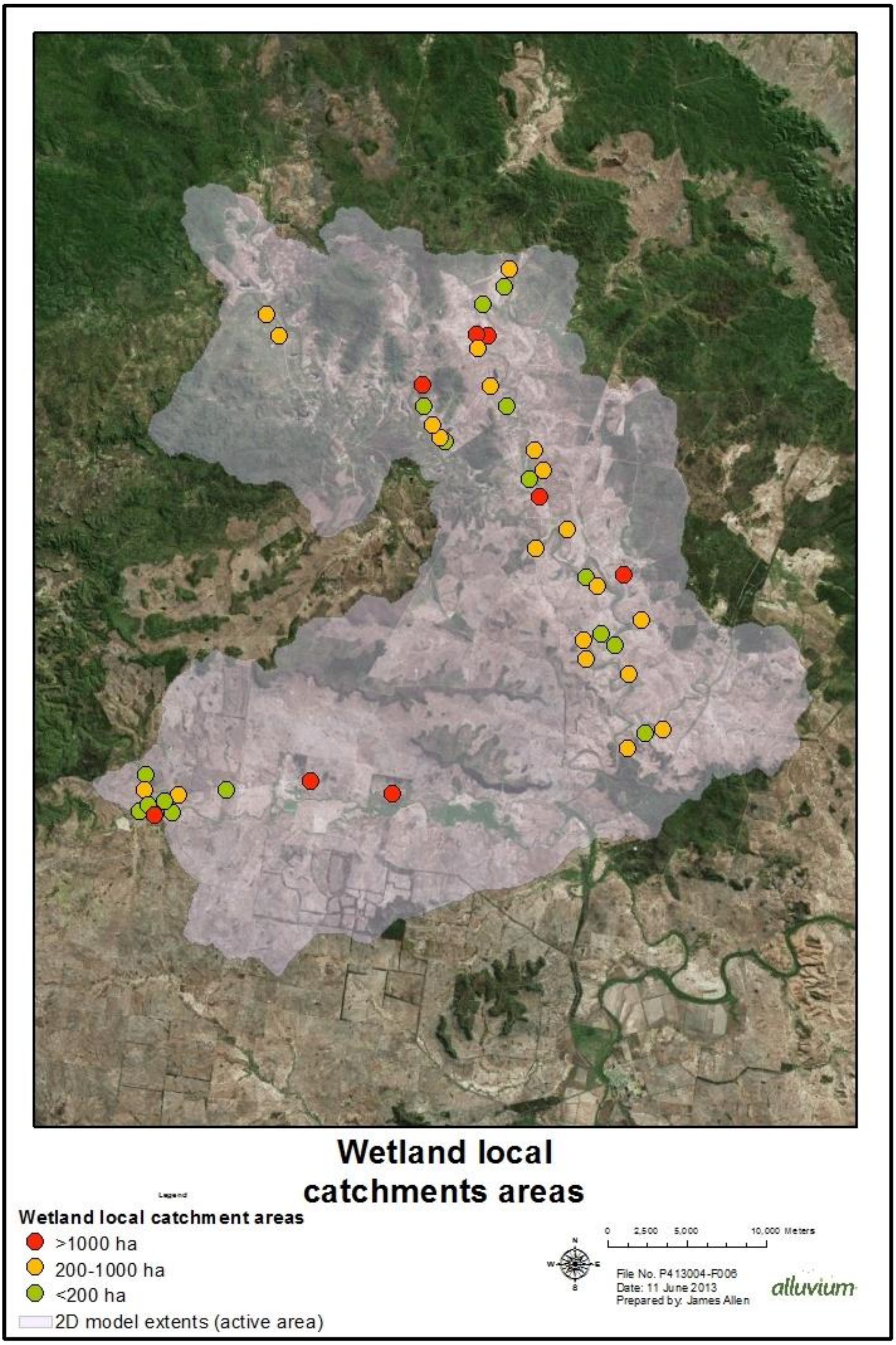

Figure 12. Wetland local catchment areas

There is a small to moderate positive correlation between wetland footprint area and local catchment area (Figure 10), driven mostly by the effect of sub-catchments larger than 1000ha.

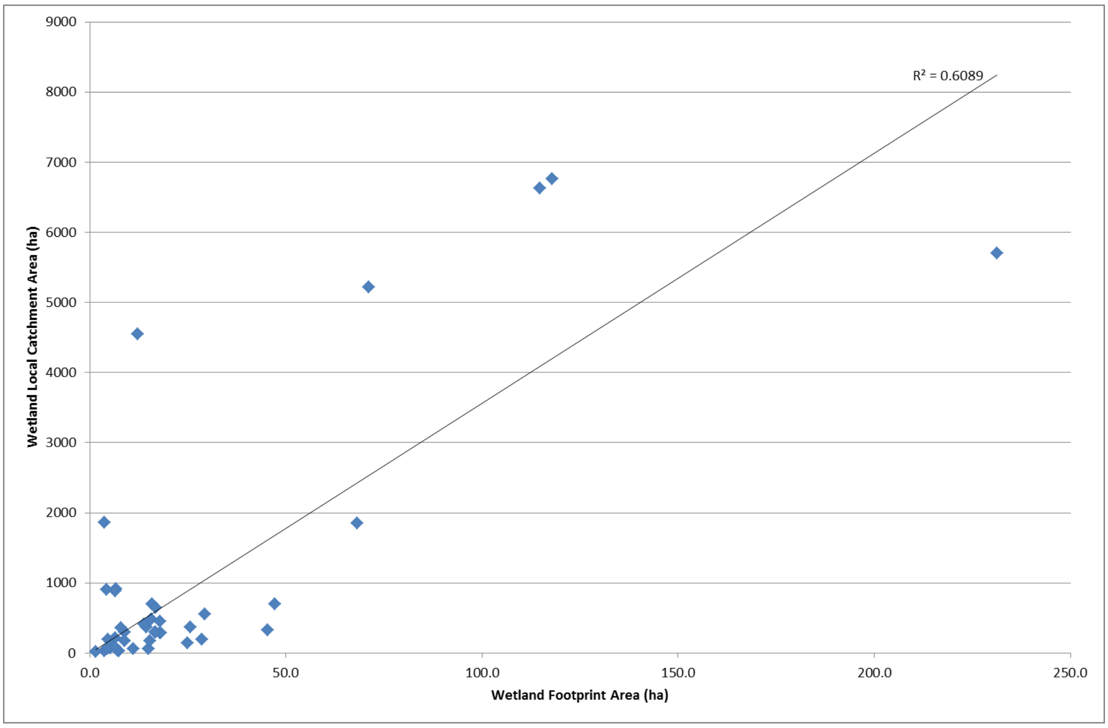

Figure 10. Wetland footprint area versus local catchment area

3.4.3 Historical gauged stream and rainfall data

A comparison between the gauged stream flow data at the La Palma gauging station on middle Palm Tree Creek and the gauged rainfall data at La Palma gauging station and the Taroom Post Office gauging station (27km south) is presented in Figure 14. These stations were chosen due to their length of records and are considered representative enough to improve our understanding of the relationship between annual rainfall and stream flow in the Palm Tree Creek system. Robinson Creek gauged stream flow data was from a more restricted period and therefore not suitable for comparisons. Any observed patterns should be treated with caution, given the distance between these recording stations, limitations in calibration of stream flow data, and gaps in reliable operation of stream gauges.

In general, substantial annual rainfall does not always result in the largest annual discharge (the protracted 2010 wet event being an exception where very high annual rainfall was matched with high discharge). A more common yet subtle trend is for the high discharge years to follow extended periods of above average rainfall. This suggests that antecedent conditions have a substantial impact on the resulting runoff from the catchment, perhaps due in part to a greater level of longer term storage being created in the system within the non-riverine wetlands and groundwaters.

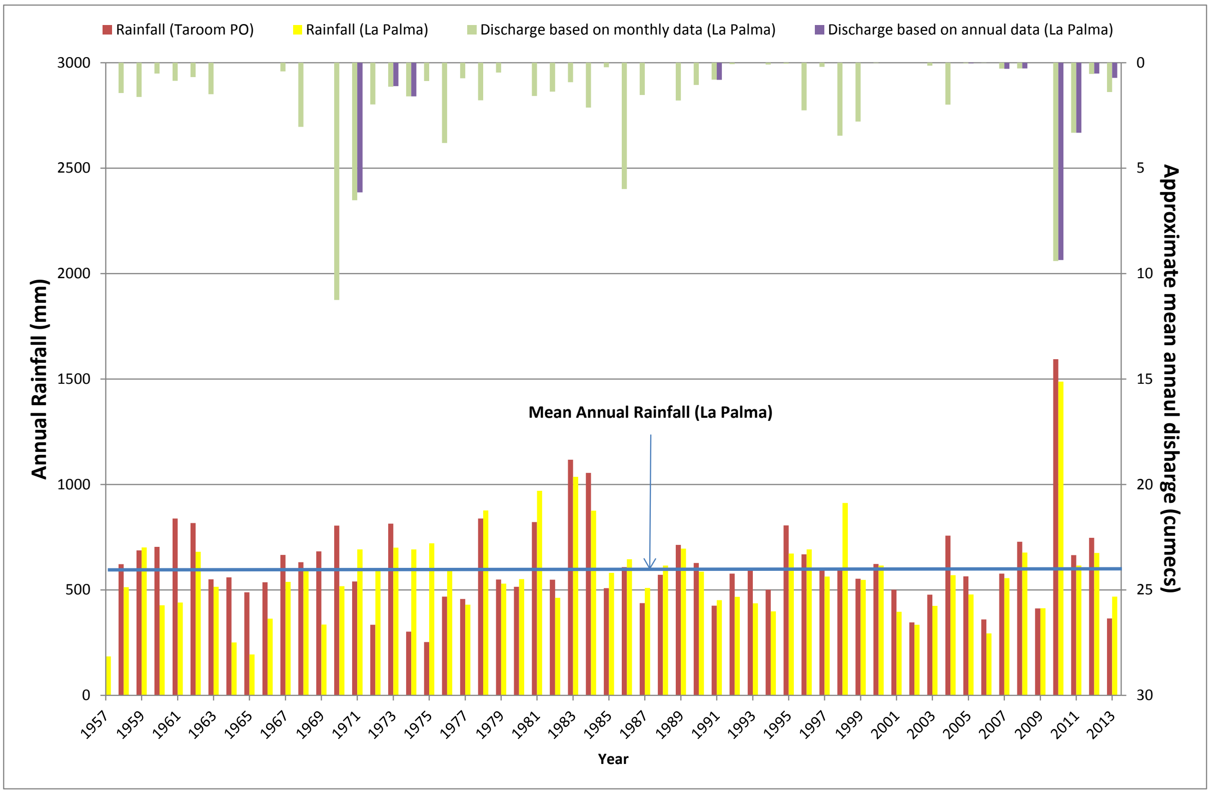

Figure 14. Historical gauged stream flow (lower Palm Tree Creek at La Palma) and rainfall data (1957-2013).

3.5 2D flood modelling

The 2D flood modelling was undertaken to estimate flood extents throughout the study area for 1 year, 2 year, 5 year and 10 year ARI events. The flood extents from this modelling are presented in a series of images (Figure 1515 to Figure 21). For the wetlands identified for analysis Figure 22 presents each wetland as a coloured point on the map, with the colour representing the frequency of riverine flood interaction that the particular wetland has been estimated to experience. Table 5 lists the wetlands assessed and the frequency of riverine interaction predicted by 2D flood modelling. As noted above, these results are only indicative due to the broad scale nature of data available for hydrologic and 2D flood modelling.

Figure 22 shows the 2D flood modelling has predicted the riverine interaction of over half of the wetlands studied in both catchments to occur during any 1 year ARI event (i.e. rainfall events which occur on average once per year). Approximately 70% of wetlands analysed had a predicted riverine interaction of a 10 year ARI event or even more frequent (smaller) event. Also, the further upstream a wetland was in both catchments, the less frequently riverine interaction tended to occur.

These combined models agree in general with local landholder observations. Together they indicate that flooding of the Palm tree Creek and Robinson Creek wetlands broadly display the following patterns:

- The wetlands are filled through a combination of local catchment and main stream (riverine) overflow, but may at times rely on riverine overflows to achieve complete filling.
- Over 50% of wetlands are filled by riverine overflow at least through 1 year ARI events; these are mostly in the lower catchment.
- Wetlands in the upper catchments (upstream of the flat alluvial plains) tend to fill less frequently from riverine influence than those lower down.
- Approximately 70% of wetlands should fill in a 10-year ARI, and these larger events assist greater flooding of wetlands in the upper catchment.

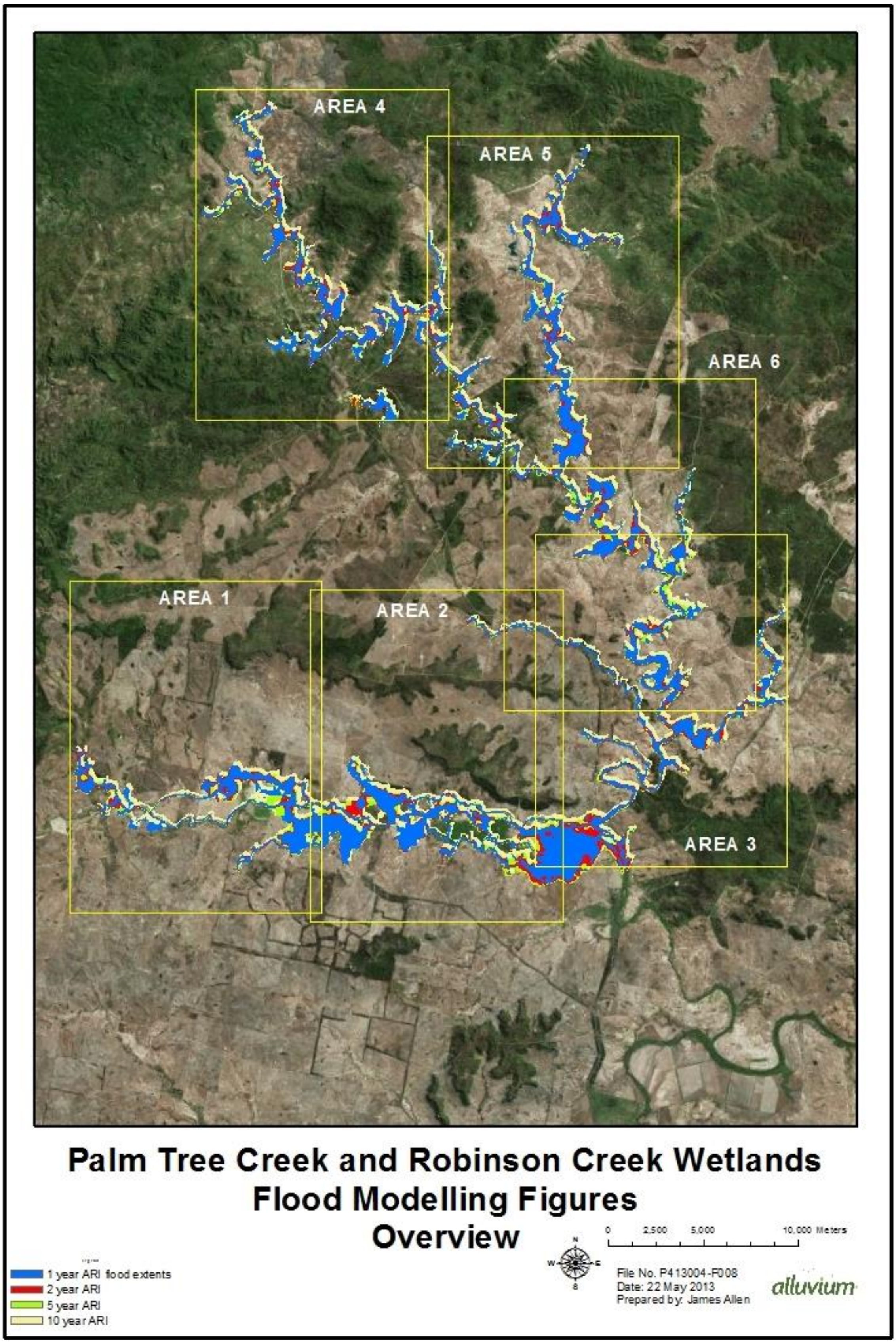

Figure 15 Overview of Flood Modelling

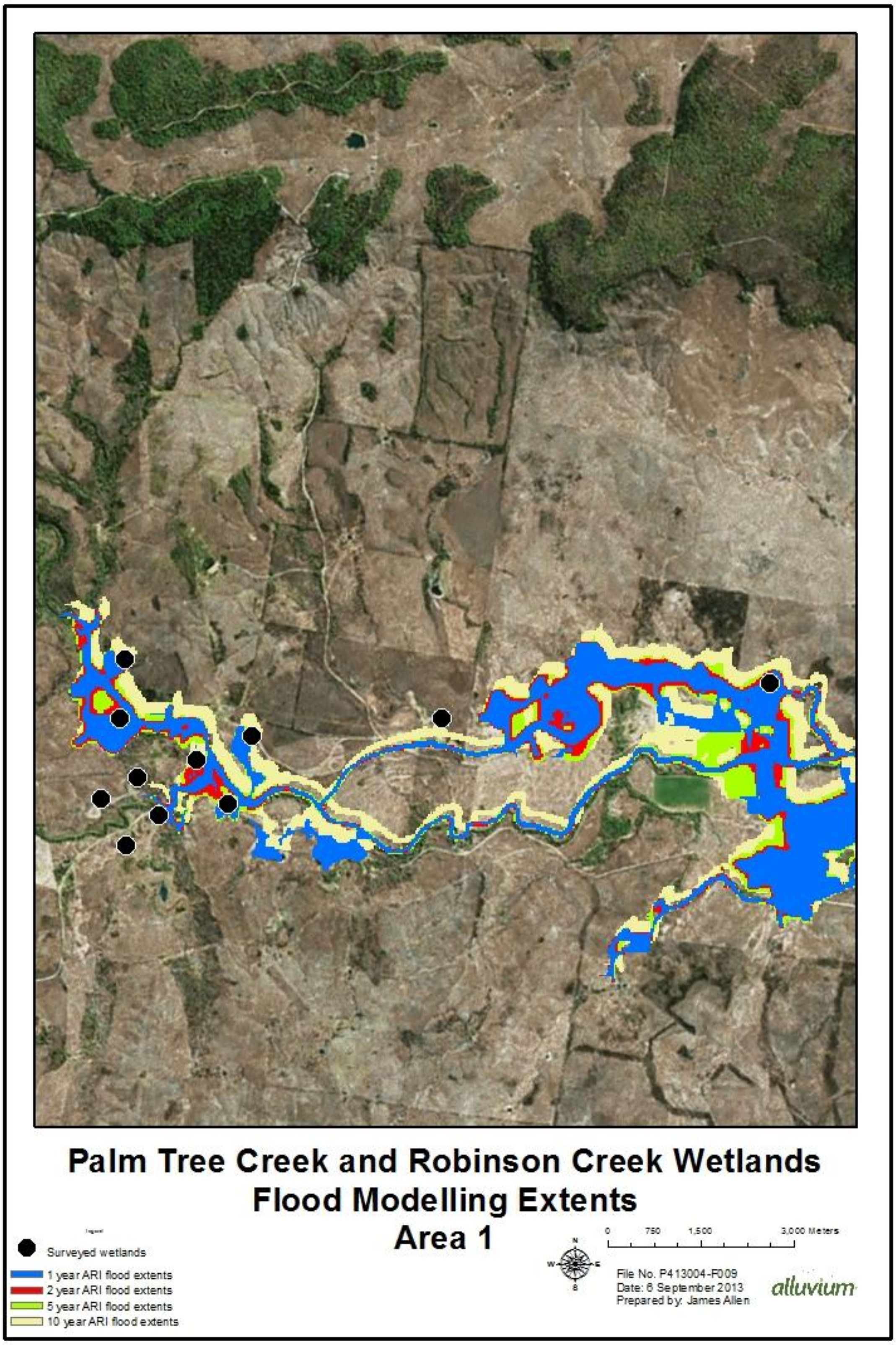

Figure 16. Flood modelling extents – Area 1

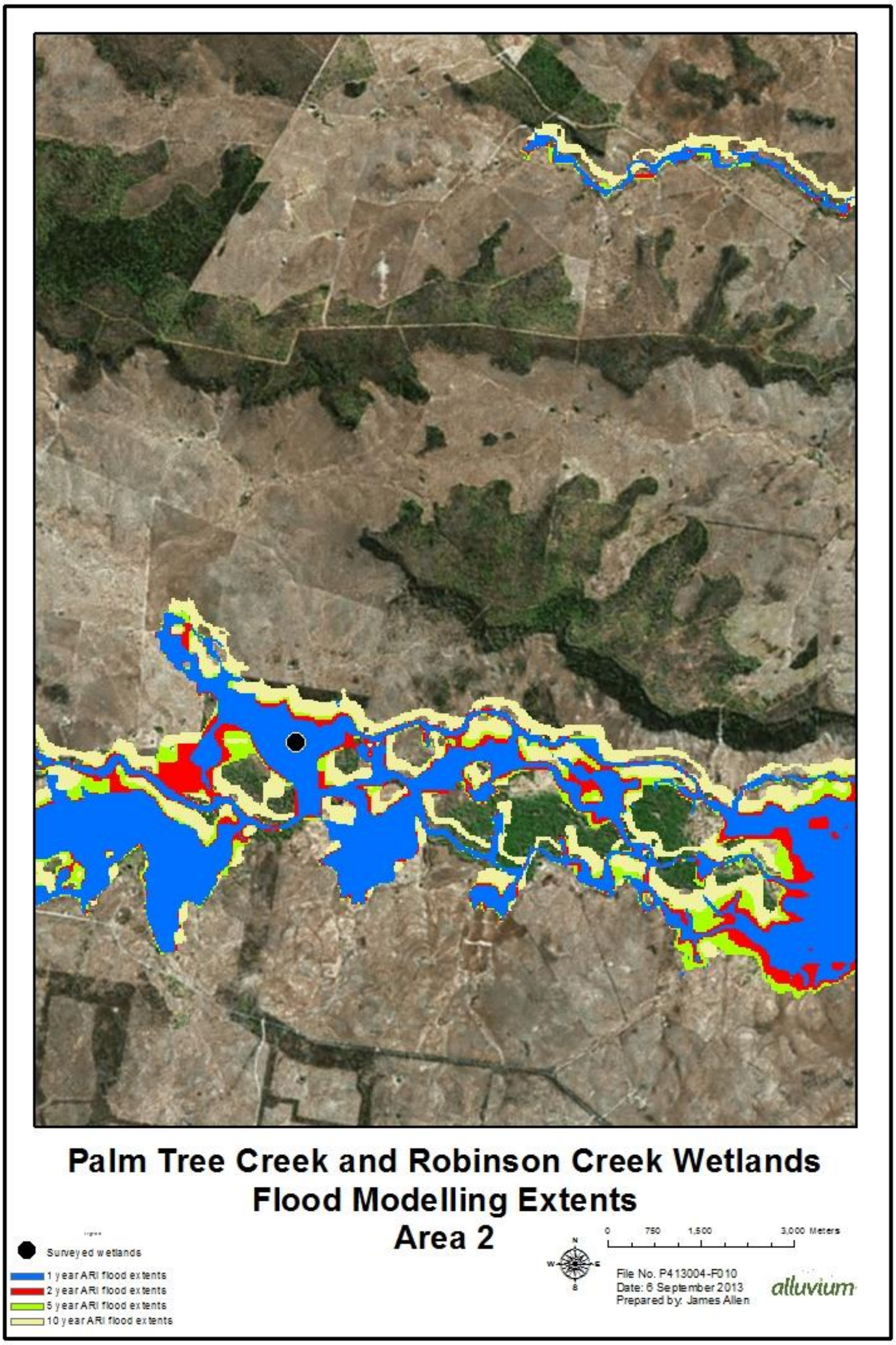

Figure 17. Flood modelling extents – Area 2

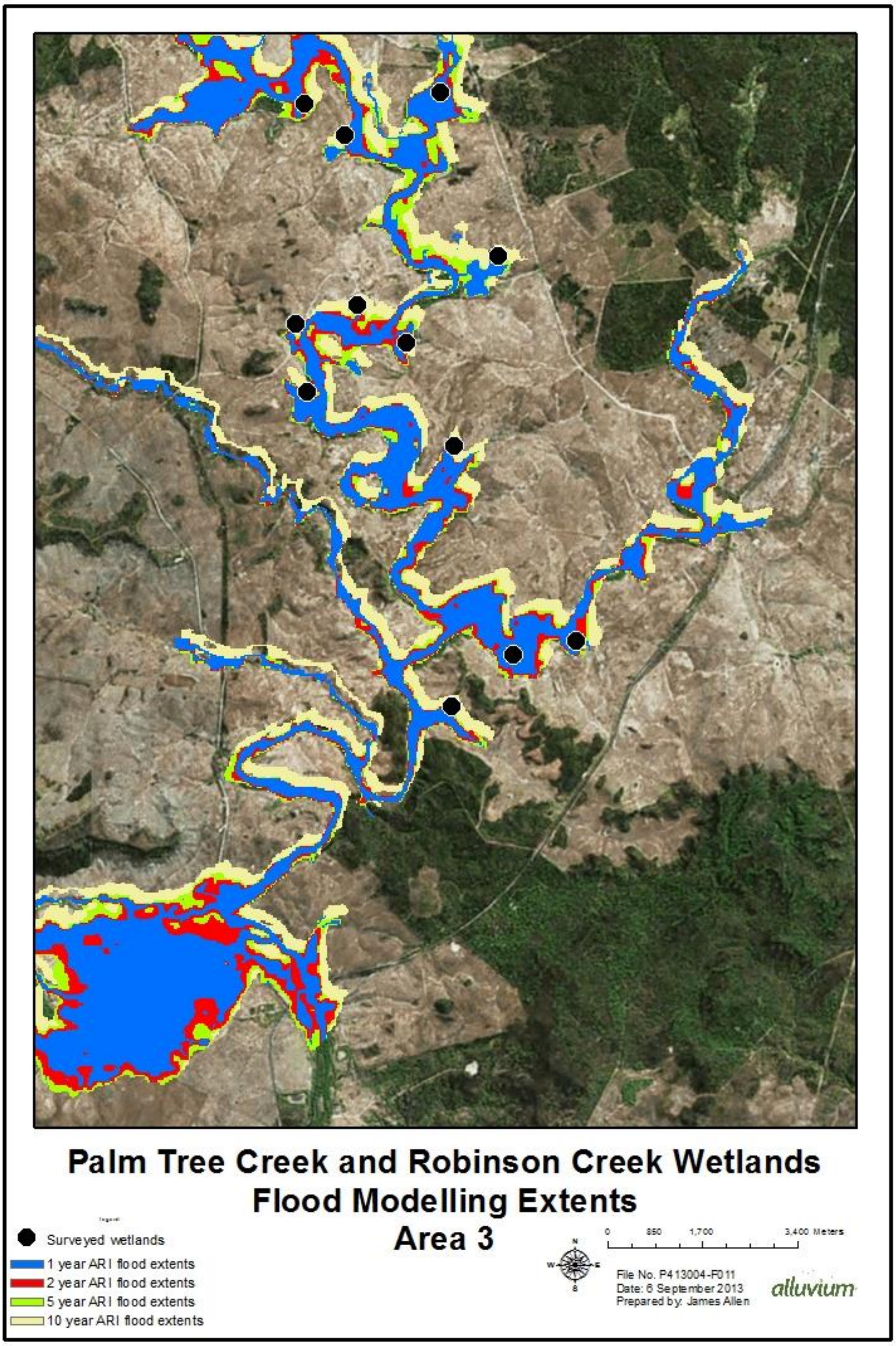

Figure 18. Flood modelling extents – Area 3

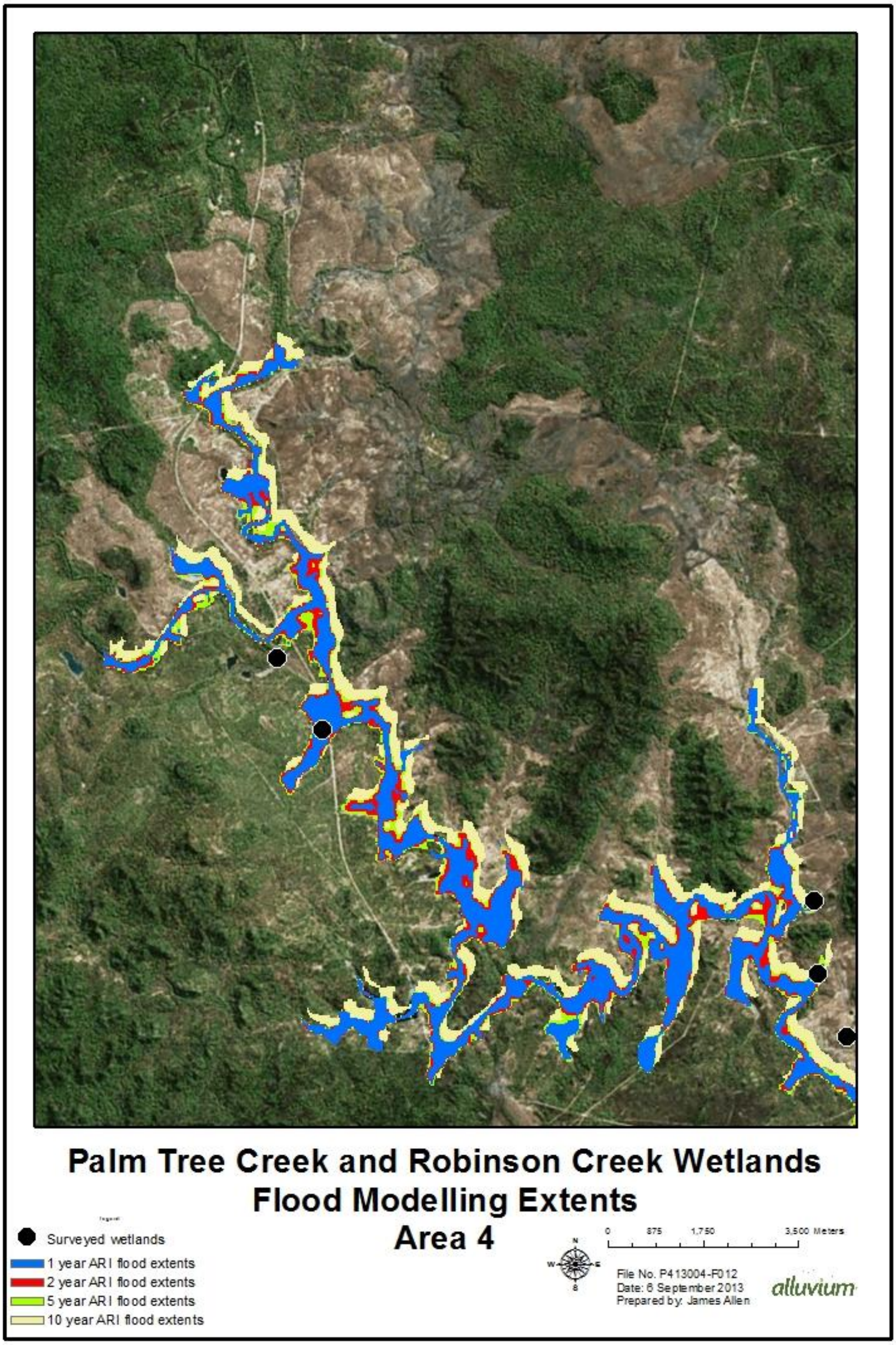

Figure 19. Flood modelling extents – Area 4

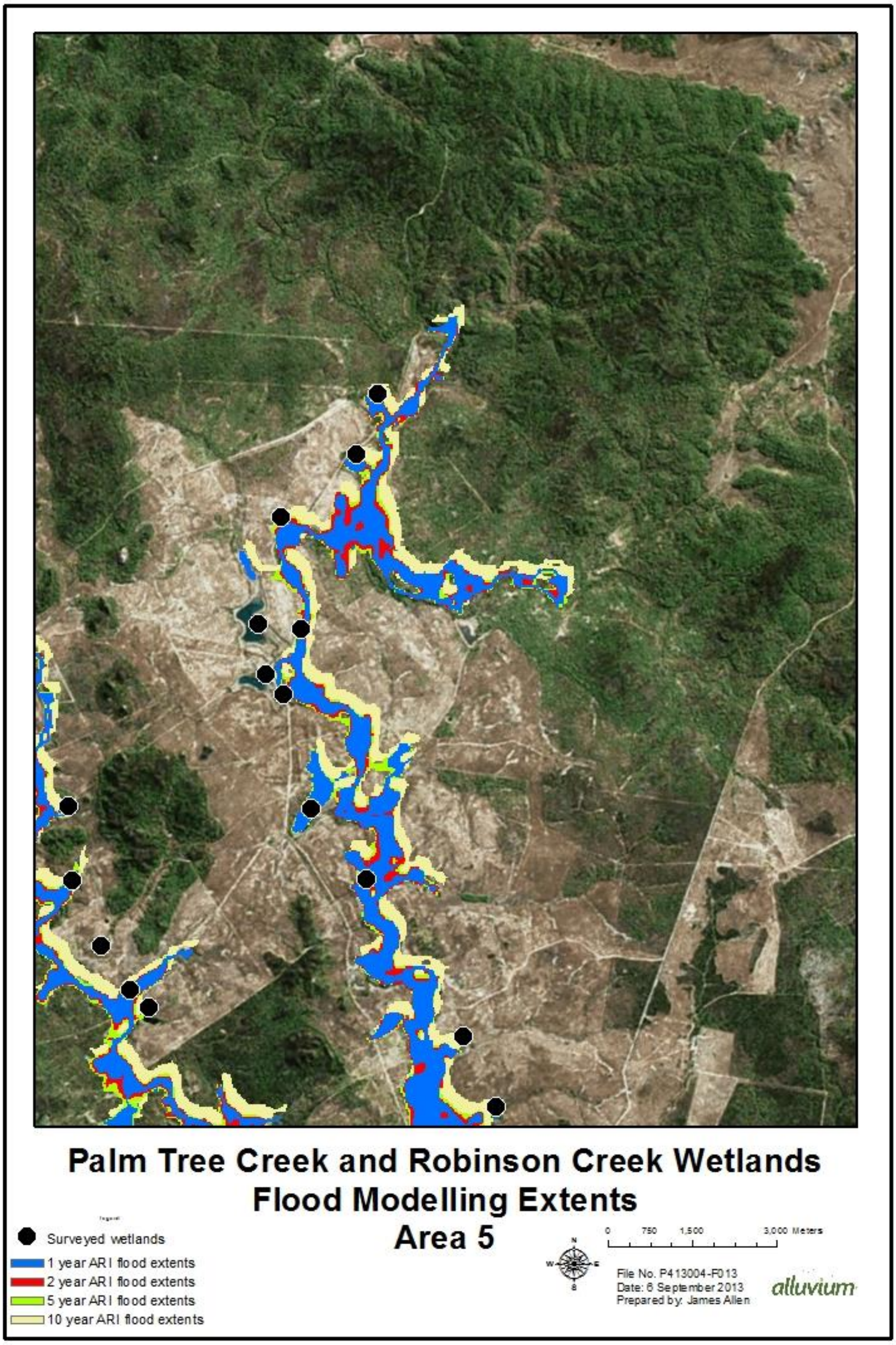

Figure 20. Flood modelling extents – Area 5

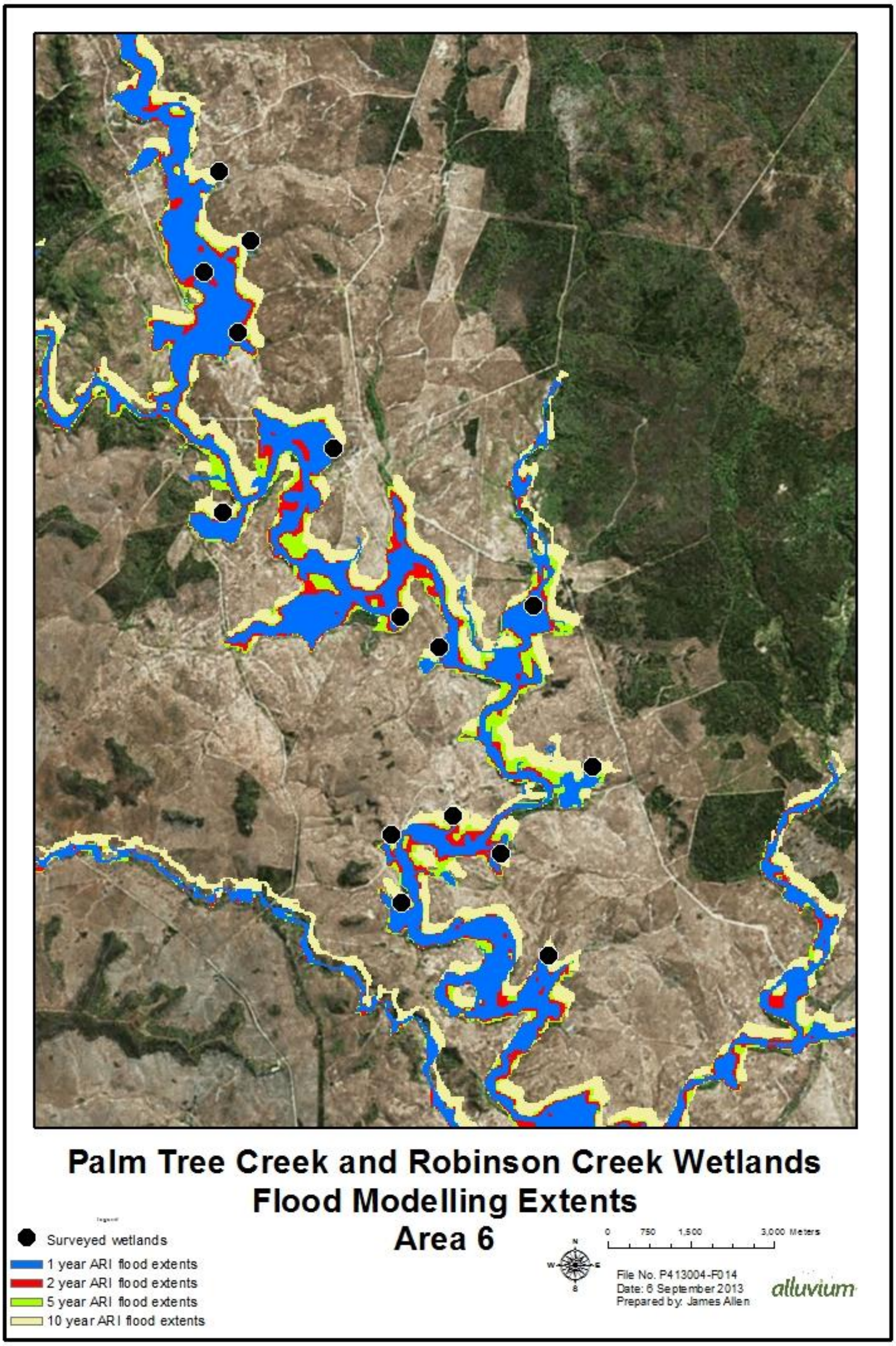

Figure 21. Flood modelling extents – Area 6

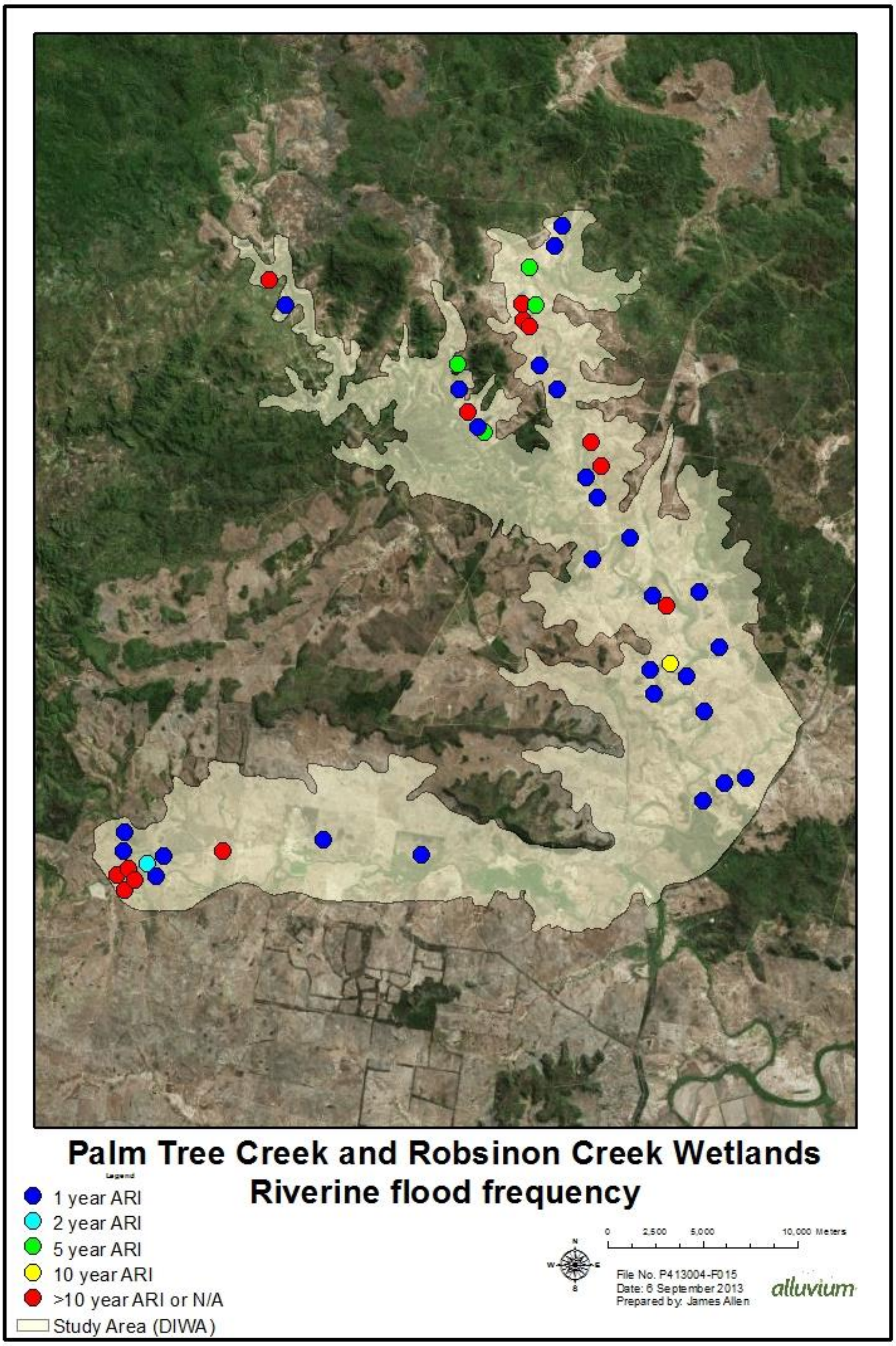

Figure 22. Riverine flood frequency of interaction with non-riverine wetlands estimated from the 2D modelling at wetlands surveyed for vegetation.

Table 5. Frequency of riverine flood interaction with non-riverine wetlands (from 2D modelling)

Wetland ID number for assessment	Creek	Reach	Frequency of riverine interaction
1	Robinson	Lower	1 year ARI
2	Robinson	Lower	1 year ARI
3	Robinson	Upper	>10 year ARI*
4	Robinson	Upper	1 year ARI
5	Robinson	Upper	1 year ARI
6	Robinson	Upper	1 year ARI
7	Robinson	Upper	>10 year ARI*
8	Robinson	Upper	>10 year ARI*
9	Robinson	Upper	1 year ARI
10	Robinson	Upper	2 year ARI
11	Palm Tree	Lower	1 year ARI
12	Palm Tree	Lower	1 year ARI
13	Palm Tree	Lower	1 year ARI
14	Palm Tree	Lower	1 year ARI
15	Palm Tree	Lower	1 year ARI
16	Palm Tree	Lower	1 year ARI
17	Palm Tree	Lower	>10 year ARI*
18	Palm Tree	Lower	10 year ARI
19	Palm Tree	Lower	1 year ARI
20	Palm Tree	Lower	1 year ARI
21	Palm Tree	Lower	1 year ARI
22	Palm Tree	Lower	1 year ARI
23	Palm Tree	Lower	1 year ARI
24	Palm Tree	Lower	1 year ARI
25	Palm Tree	Lower	1 year ARI
26	Palm Tree	Lower	>10 year ARI*
27	Palm Tree	Lower	>10 year ARI*
28	Palm Tree	Mid	1 year ARI
29	Palm Tree	Mid	1 year ARI
30	Palm Tree	Mid	5 year ARI
31	Palm Tree	Mid	5 year ARI
32	Palm Tree	Mid	>10 year ARI*
33	Palm Tree	Mid	>10 year ARI*
34	Palm Tree	Mid	1 year ARI
35	Palm Tree	Mid	1 year ARI
36	Palm Tree	Mid	5 year ARI
37	Palm Tree	Mid	1 year ARI
38	Palm Tree	Mid	>10 year ARI*
39	Palm Tree	Mid	5 year ARI
40	Palm Tree	Mid	1 year ARI
41	Robinson	Upper	>10 year ARI*
42	Palm Tree	Upper	>10 year ARI*
43	Palm Tree	Upper	1 year ARI
44	Palm Tree	Lower	1 year ARI

*A larger (less frequent) event than a 10 year ARI event e.g. a 50 year ARI event.

3.6 Water balance assessment

Only a simple water balance assessment was possible because of the limited resolution of topographic data and paucity of local groundwater and evaporation data. Thus the assessment only examined surface water contributions from local catchment runoff and excluded evaporation and groundwater influence. The mean annual rainfall and 1 year ARI 18 hour duration event (see section 2.2) were chosen for this assessment due to their relatively high likelihood of occurrence in an average year.

Wetland bathymetry data does not exist here. For the purposes of simple water balance assessments, depth was considered to be uniform across the whole wetland area. Actual bathymetry in most of these wetlands, according to local knowledge and observations by survey teams, includes gently sloping sides that reach maximum depths of approximately 1 - 2.5m.

The results of this assessment are presented in Table 6. These preliminary results, supported by analyses of historical imagery, local observations and flood models, indicate that surface water has a substantial influence on hydrology of these wetlands and groundwater influence is likely to be relatively small, for example:

1. 27 of the 44 wetlands assessed are predicted to fill to a depth of 1m or greater from the volume of local sub-catchment runoff <u>from a 1 year ARI 18 hour duration</u> (62.1mm) rainfall event. This indicates a substantial contribution of wetland filling from local catchment runoff.
2. All 44 of the wetlands assessed are predicted to fill to a depth of 2m or greater from the volume of local sub-catchment runoff <u>from the total mean annual rainfall</u> for the region of approximately 670mm (obtained from the Bureau of Meteorology's Weather Station Directory). In fact the total annual runoff of local sub-catchments in an average rainfall year would equate to filling most of them to at least 6 times their normal full volume (though this does not consider any losses due to evaporation, drainage and infiltration).

Local observations commonly note that many non-riverine wetlands begin to lose water with each dry season. This concurs with analyses of inundated areas on Landsat imagery and indicates that groundwater resources may have relatively limited contribution to wetland inundation during periods of low surface flow (baseflow conditions). Nevertheless, large swamps and lakes in the lower Palm Tree Creek and Robinson Creek catchments also remain wet for longer periods up to several years (see local observations and results of 2D flood modelling on riverine interaction). Apart from riverine influences, the prolonged inundations in these lower parts of the catchment suggest that some groundwater supply might contribute to baseflows here. This evidence indicates that a much better understanding of groundwater interaction and influence on wetland inundation during baseflow conditions is needed for this system.

Improvements in local topographic data would enable much more reliable modelling and understandings of the comparative contributions of local sub-catchment versus riverine sources of surface water to fill these wetlands.

Assumptions and Limitations

- This assessment used Google Earth imagery to derive wetland full surface area. This approach was determined to better represent wetland full surface areas compared to the 100,000 topographic wetland footprints available from Queensland Government resources.
- For these water balance assessments, water depths in the wetlands have been estimated based on the assumption of a non-sloping flat bed. In reality depth is not uniform.
- Water depth in wetlands has been used as an indicative measure of the potential of local runoff in being able to fill the wetlands. Given there is anecdotal evidence and field observations that the wetlands can have depths around 1 to 2 metres when full, depth was considered a better measure of filling potential than volume for the presentation of these results.
- This assessment has intentionally focussed on the potential for local runoff to fill the wetlands independent of the contribution riverine interaction may make. Any reliable estimates of contributions from riverine interaction are difficult to derive because of the limited resolution of topographic data. Riverine interaction with the wetlands has therefore only been assessed and presented in Section 3.5 in terms of the potential for interaction during various flood events.

Table 6. Riverine flood frequency of interaction with wetlands

Wetland ID number for project	Creek	Approximate wetland full surface area (ha)	Wetland depths from Mean Annual Rainfall (MAR) local runoff (m)	Wetland depths from 1 year ARI 18 hour duration event local runoff (m)
1	Robinson	231	16.50	1.53
2	Robinson	118	38.45	3.56
3	Robinson	7	2.35	0.22
4	Robinson	18	10.68	0.99
5	Robinson	5	28.42	2.63
6	Robinson	18	10.48	0.97
7	Robinson	15	2.49	0.23
8	Robinson	7	3.50	0.32
9	Robinson	2	10.32	0.96
10	Robinson	4	5.70	0.53
11	Palm Tree	7	92.08	8.53
12	Palm Tree	29	4.54	0.42
13	Palm Tree	6	92.00	8.53
14	Palm Tree	17	11.86	1.10
15	Palm Tree	8	30.14	2.79
16	Palm Tree	5	12.69	1.18
17	Palm Tree	9	21.87	2.03
18	Palm Tree	11	3.42	0.32
19	Palm Tree	17	12.08	1.12
20	Palm Tree	5	9.49	0.88
21	Palm Tree	18	16.77	1.55
22	Palm Tree	26	9.70	0.90
23	Palm Tree	9	13.27	1.23
24	Palm Tree	45	4.89	0.45
25	Palm Tree	38	1161.03	107.61
26	Palm Tree	14	17.13	1.59
27	Palm Tree	16	29.38	2.72
28	Palm Tree	6	21.91	2.03
29	Palm Tree	5	13.98	1.30
30	Palm Tree	6	8.73	0.81
31	Palm Tree	4	338.19	31.35
32	Palm Tree	68	18.22	1.69
33	Palm Tree	16	20.93	1.94
34	Palm Tree	47	9.97	0.92
35	Palm Tree	25	3.95	0.37
36	Palm Tree	4	8.93	0.83
37	Palm Tree	29	12.75	1.18
38	Palm Tree	14	20.03	1.86
39	Palm Tree	12	252.01	23.36
40	Palm Tree	15	7.77	0.72
41	Robinson	115	38.69	3.59
42	Palm Tree	4	143.72	13.32
43	Palm Tree	17	25.88	2.40
44	Palm Tree	71	49.21	4.56
		Median depth (m):	**13.62**	**1.26**

4 Discussion

This section discusses the overall findings of surface water hydrology modelling, local landholder observations, other literature and analysis of historical Landsat images for the Palm Tree Creek and Robinson Creek wetlands. It summarises these findings to describe and comment on:

- the hydrological behaviour of the wetlands
- the relative role of surface water and potential influence of groundwater in this system.

Limited discussion on hydrological issues associated with climate variability is also provided.

4.1 Hydrological and 2D flood models

Surface water influences:

The filling of the Palm Tree Creek and Robinson Creek floodplain swamps and lakes appears to be dominated by surface water hydrology, including 1) filling from local runoff and small streams and 2) riverine flooding from Palm Tree Creek and Robinson Creek. This conclusion is based on:

- Apart from a few local anomalies, the relative size of the non-riverine wetlands shows some correlation with the size of the local catchments feeding them. This suggests the wetlands may be geomorphically formed, or at least maintained by runoff from their local catchments.
- Local catchment runoff has the potential to contribute substantially to the filling of the wetlands under both a 1 year ARI event scenario and a mean annual rainfall scenario.
- The flood modelling results show more than 50% of the non-riverine wetlands studied experience riverine interaction with 1-year ARI flood events (with some potentially interacting during even smaller flood events); and approximately 70% of wetlands studied had riverine interaction with 1-year ARI to 10-year ARI flood events.
- There appears to be general agreement across local landholder observations that wetlands frequently fill through their connections to the main streams (Palm Tree Creek and Robinson Creek).

This study did not identify any relationship between the frequency of the wetland riverine interaction and the size of the local catchment area for individual wetlands.

The flood modelling results tend to indicate that the further upstream in the catchment the wetlands are located, the less frequent the riverine interaction.

Local landholder observations and Landsat images of historical flood extents in general support the broad patterns estimated by the 2D model.

Wetlands in the Robinson Creek catchment are fewer, mostly larger and often wet for longer periods than those in the Palm Tree Creek catchment. Local landholder observations and regional surface geology mapping concur that slightly higher alluvial clay contents in the Robinson Creek wetlands and streams may partly contribute to the longer water retention periods here compared to the smaller, more ephemeral wetlands of the Palm tree Creek catchment.

It should be noted, however, that due to the coarse resolution of the topographic data and limitations with gauged flow data, the surface water modelling results should be used with some caution.

Groundwater influences:

Accordingly, whilst groundwater appears to have relatively little influence on hydrology of these wetlands, the potential for groundwater interaction and influence on parts of the system requires much better understanding, especially during periods of low surface flow (baseflow). If groundwater table levels and substrate permeability are suitable, local recharge from alluvial groundwater systems can lead to more constant wetlands (eg, potentially at Lake Murphy and other wetlands in the lower catchment). Wetlands which are connected to the hyporheic flows of shallow groundwater systems can also recharge local groundwater systems, which can quicken the speed of wetlands drying out. An important point to note in assessing hyporheic groundwater influence is that hyporheic flow and groundwater flow tend be clear (not turbid), compared to surface water flow.

Two GAB recharge area springs confirmed just downstream of the study area (see above) indicate potential for future discovery of groundwater dependant systems in the Palm Tree Creek and Robinson Creek catchment. The presence of GAB springs nearby the site, existing agricultural land use plus potentially increasing resource exploration and development in the region, reinforces the need for further hydrogeological investigations into groundwater discharge in the study area, with a focus on potential links with the Hutton Sandstone and Eurombah Formation.

We recommend further investigations into alluvial and artesian groundwater resources and springs and their potential influence on Palm Tree and Robinson Creek wetlands and streams.

Sedimentation:

Sedimentation of these wetlands appears to be causing significant shallowing and lateral expansion of wetlands, particularly on the alluvial plains of the lower catchments. Tree deaths around the perimeters of these large lakes in the lower catchments is further evidence of this. These changes may lead to more widespread flooding and alterations to watercourses during large rainfall events and are a concern for many landholders. An adequate understanding of the causes of sediment infilling in wetlands would require more dedicated fluvial geomorphology studies, coupled with assessments of soils, vegetation cover and erosion across the landscape.

4.2 Impact of climate change on drought and flood regimes

The Queensland Government document "*Increasing Queensland's resilience to inland flooding in a changing climate: Final Report on the Inland Flood Study*" provides an interim guidance for factoring climate change into flood studies (Queensland Government 2010). Intended specifically for use in flood risk management and land use planning purposes as described by the *State Planning Policy* (SPP 1/03), these are interim guidelines only and were presented with several caveats, eg:

- The methods do not extend to events more frequent than the 1 percent (Q_{100}) AEP flood events, and the shortest time frame addressed in the document is the year 2050, 37 years from now.
- The guidelines were based on results of the *Inland Flood Study* for Gayndah in the north Burnett Catchment and should be treated with caution when applying to other regions.
- The guidelines will require a review and update when a national position on how to factor climate change into flood studies is finalised as part of the current review of the Australian Rainfall and Runoff (AR&R, Kuczera and Frank 2012).
- The climate change factor (of 5% rainfall intensity increase per degree of global warming) should be applied to rainfall depths/intensities and not directly to hydrographs (i.e. the quantity of water flowing in the river). The scaled rainfall depths/intensities should then be applied to the hydrological model in the same way as the current event-based methods to produce design flood hydrographs for climate change scenarios.

With the above caveats in mind, the interim guideline recommendations include adopting a 2 degree Celsius temperature increase for 2050 and applying a 5% rainfall intensity increase for each degree Celsius temperature increase. In effect, this requires consideration of a 10% increase on existing rainfall intensities to account for climate change in the year 2050.

Modelling to test the potential impacts of climate variability on future storm and flood events for this area was outside the scope set for this project. However this would be a very useful future study for local landholders, local council and regional authorities.

5 Recommendations

Accuracy and reliability of findings from the current hydrological study are limited by the extent and quality of recorded surface water and groundwater data. Recommendations arising from the study are listed to help address these limitations as well as inform management planning for maintaining ecological processes and values of the Palm Tree Creek and Robinson Creek wetland and stream systems:

- Acquiring high resolution terrain data such as LiDAR data is recommended to enable more detailed surface water modelling. It would improve the digital representation of the wetlands, floodplains and creek channels and the accuracy of hydrologic and 2D flood modelling. This would also improve understanding of how the wetlands fill and drain.
- Improved surface water gauged data (local rainfall and, most importantly, stream gauge data determined using accurate rating curves) in Palm Tree Creek in particular for which the gauged flow data was judged to be unreliable at both gauging stations.
- If future predictions on climate change are to be attempted, it would be dependent on revisions of the Queensland guidelines for factoring climate change into flood modelling (Queensland Government 2010) and review of the current Australian Rainfall and Runoff guideline (AR&R, Kuczera and Frank 2012).
- We recommend further investigations into alluvial and artesian groundwater resources, springs and their potential influence on the wetlands and streams of Palm Tree and Robinson Creeks. This may also include the testing of water samples (possibly for electrical conductivity) obtained for the more permanent streams and non-riverine wetlands as they dry to identify potential sources of ground water contributing to the wetlands.
- A dedicated fluvial geomorphology study will improve the understanding of sediment sources and explanations to wetland shallowing and expansion. If coupled with assessments of soils, vegetation cover and erosion across the landscape, this would also help to identify where in the catchment system the problems can be more effectively mitigated.

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7 Appendices

Table 7 Comparison of wetland surface area to local runoff sub-catchment area for 44 assessed wetlands.

ID number	Creek	Wetland footprint area (ha)	Local runoff catchment area (ha)
9	Robinson	1.5	23.1
31	Palm Tree	3.7	1861
10	Robinson	3.7	31.8
42	Palm Tree	4.2	906.3
36	Palm Tree	4.4	58.8
5	Robinson	4.6	193.1
16	Palm Tree	5.0	94.1
20	Palm Tree	5.2	73.5
29	Palm Tree	5.3	110.3
30	Palm Tree	6.4	83.9
13	Palm Tree	6.5	889.1
28	Palm Tree	6.5	212.5
11	Palm Tree	6.7	919.9
8	Robinson	7.0	36.6
3	Robinson	7.4	25.8
15	Palm Tree	8.0	358.5
23	Palm Tree	8.9	176.7
17	Palm Tree	9.0	292.3
18	Palm Tree	11.1	56.6
39	Palm Tree	12.1	4554.1
38	Palm Tree	13.8	412.7
26	Palm Tree	14.5	370.1
7	Robinson	15.0	55.8
40	Palm Tree	15.4	178.7
33	Palm Tree	15.6	487.5
27	Palm Tree	15.9	698.6
19	Palm Tree	16.5	298.4
43	Palm Tree	16.7	646.4
14	Palm Tree	16.8	297.8
21	Palm Tree	17.9	448.3
4	Robinson	17.9	286
6	Robinson	18.1	283.8
35	Palm Tree	24.8	146.5
22	Palm Tree	25.6	370.5
12	Palm Tree	28.6	193.9
37	Palm Tree	29.3	557.1
25	Palm Tree	37.8	65525.3
24	Palm Tree	45.3	330.7
34	Palm Tree	47.2	702.5
32	Palm Tree	68.2	1854.4
44	Palm Tree	71.1	5223.2
41	Robinson	114.8	6627.6
2	Robinson	117.9	6767.3
1	Robinson	231.3	5697.7

Our country, Our future.

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FITZROY BASIN ASSOCIATION

Local Perspectives Report

FITZROY BASIN ASSOCIATION

Our country, Our future

Local Perspectives Report – Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by Alluvium Consulting Australia for Fitzroy Basin Association Inc.

Australian Government

Santos
GLNG Project

Local Perspectives - Palm Tree & Robinson Creek Wetlands

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This report was prepared on behalf of FBA by Alluvium Consulting Australia Pty Ltd.

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Our country, Our future

Summary

This report presents an exploration of the natural history of the Palm Tree Creek and Robinson Creek Wetlands through the eyes of local community members.

It represents one of a suite of investigations, commissioned by the Fitzroy Basin Association Inc. (FBA) and implemented by Alluvium Consulting Australia Pty Ltd (Alluvium), which aim to build a better understanding of the natural and cultural values of this wetland system. The other studies relate to the system's fauna, flora, hydrology and geomorphology.

The results of these investigations will contribute to a technical report, including maps, models and photographs, that will inform a management plan for the wetlands (to be delivered by FBA, in partnership with landholders). They will also contribute to a non-technical publication (e.g. a coffee-table book), designed to shed light on the processes and values of the wetlands, which will be accessible to the broader community.

The network of swamps, lagoons and lakes of the Palm Tree and Robinson Creeks are listed in the *Directory of Important Wetlands in Australia* (Environment Australia 2001), yet very little is documented about their significance. The system covers an area of 50 223 ha. It is located within the upper Dawson River catchment in central-east Queensland's Fitzroy Basin. The closest urban centre is the township of Taroom.

For this study thirteen locals, whose families have lived and worked by these wetlands for generations, were engaged to share their stories, personal recollections and family photo collections, during seven separate interviews conducted during March and April 2013. The majority of those interviewed had a connection to wetlands on the Robinson Creek; three shared their insights on the wetlands of the Palm Tree Creek. These interviews were designed to help build a picture of how the wetlands function and how they have changed over time. They were also intended to gain insight into the social significance of the wetlands and to uncover some of the stories and personalities of the people who know them well.

This report begins by providing background on the study area: the natural landscape, history of settlement and land use. It then presents edited versions of the seven interviews; written in the third person as succinct stories and accompanied by photos, both new and archival.

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Glossary and Acronyms

Alluvium	Alluvium Consulting Australia Pty Ltd
FBA	Fitzroy Basin Association Inc.
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities

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1 Introduction

1.1. Purpose

The network of swamps, lagoons and lakes of the Palm Tree and Robinson Creeks are listed in the *Directory of Important Wetlands in Australia* (Environment Australia 2001), yet very little is documented about their significance.

This report presents an exploration of the natural history of these wetlands through the eyes of local community members. It represents one of a suite of investigations, commissioned by the Fitzroy Basin Association Inc. (FBA) and implemented by Alluvium Consulting Australia Pty Ltd (Alluvium), which aim to build a better understanding of the natural and cultural values of this wetland system. The other studies relate to the system's fauna, flora, hydrology and geomorphology.

The results of these investigations will contribute to a technical report, including maps, models and photographs that will inform a management plan for the wetlands (to be delivered by FBA, in partnership with landholders). They will also contribute to a non-technical publication (e.g. a coffee-table book), designed to shed light on the processes and values of the wetlands, which will be accessible to the broader community.

Funding for the project has come primarily from the Australian Government's *Biodiversity Fund*, under the Clean Energy Future program with additional support from Santos Limited.

1.2. Scope

This study seeks to capture the natural history of the Palm Tree Creek and Robinson Creek Wetlands through the eyes of local community members, beginning with some of the landholders in the Taroom region whose families have lived and worked by these wetlands for generations.

Thirteen locals were engaged to share their stories, personal recollections and family photo collections for the study, during seven separate interviews. The majority of those interviewed had a connection to wetlands on the Robinson Creek; three shared their insights on the wetlands of the Palm Tree Creek. The authors acknowledge that the views and opinions captured from these interviews may not entirely reflect those of others, nor provide a comprehensive understanding of the local history, uses and values of the wetlands.

These interviews were designed to help build a picture of how the wetlands function and how they have changed over time. They were also intended to gain insight into the social significance of the wetlands and to uncover some of the stories and personalities of the people who know them well.

Given the extent of the system and the limited scope of the project, it should be recognised that at best, this study captures just a snapshot, and only a partial set of perspectives on these wetlands.

2 Methods

Six face-to-face semi-structured interviews were conducted with 11 people, generally in their homes, during a three-day field visit to the Taroom region from 25-27 March, 2013. A seventh interview was conducted by telephone in April 2013.

These interviews were arranged by long-term Taroom resident, Adam Clark. Adam is Project Officer with the local branch of the Wildlife Preservation Society Queensland, who have partnered with FBA on the overall project. Adam and his wife Dorothy were themselves interviewed.

The interviews focused on exploring personal and family history stories about the wetlands: why the wetlands are important to them, how they are used, memorable sights and experiences, their visions for the future of the wetlands etc. The interviews also sought to understand how the wetlands function and how they have changed over time. During the interviews, participants often shared relevant photos from their family collection and the stories that went with them.

During April and May 2013, those interviewed were sent draft copies of the stories they had shared for the study and follow-up contact was made to check for accuracy and authenticity.

As part of the fieldwork, supporting material was sought from the Taroom Historical Society, Banana Shire Council and the Taroom local library; however little of what was sought (newspaper clippings, local histories or personal/club records on floods, fish catches, bird sightings etc.) was uncovered. Supplementary information for the report was found through a desktop review of relevant literature, primarily found online.

3 Results

3.1. Background

3.1.1 Study area

The Palm Tree and Robinson Creeks Wetland system covers an area of 50 223 ha and is characterised by a series of shallow lakes and seasonal streams (SEWPaC 2010). This system is located within the upper Dawson River catchment in central-east Queensland's Fitzroy Basin. The closest urban centre is the township of Taroom, in Banana Shire, which has a population of 629 (Banana Shire Council 2012).

The Palm Tree and Robinson Creeks Wetland system (Figure 1) is listed in the Australian Government's *Directory of Important Wetlands in Australia* (#QLD018) for two reasons:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia, and
2. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level (SEWPaC 2010).

3.1.2 Natural landscape

The study area falls within the 'Brigalow Belt South' bioregion. Bioregions are large, geographically distinct areas of land with common characteristics such as geology, landform patterns, climate, ecological features and plant and animal communities (SEWPaC 2013). The Brigalow Belt South bioregion contains mixed landscapes, including undulating to hilly areas with low ridges and deep valleys, as well as flat alluvial plains in the south. Vegetation is predominantly mixed eucalypt woodland with areas of brigalow scrubs and open grasslands (Bastin 2008).

The term 'brigalow' is used simultaneously to refer to: the tree *Acacia harpophylla* – a wattle tree with silvery foliage that grows as forests or woodlands on clay soils; an ecological community dominated by this tree; and a broader region where this species and ecological community are present (Threatened Species Network 2008).

Most brigalow dominated communities occur on 'gilgaied clay vertosols'. These are shrink-swell soils, which develop deep cracks when dry. Gilgais (commonly known as 'melon holes') are a distinctive geomorphic feature of the Brigalow Belt South, comprising a series of alternating mounds and depressions that intermittently fill with water following rainfall events (The University of Queensland 2009).

The distinctive species of palm found in the study area, and that gives Palm Tree Creek its name, is referred to variously as *Livistona nitida* (Queensland Parks and Wildlife Service 2001) and *Livistona sp.* unnamed (SEWPaC 2010), and commonly as Carnarvon Gorge cabbage palm, Carnarvon fan palm, cabbage tree palm or Dawson palm.

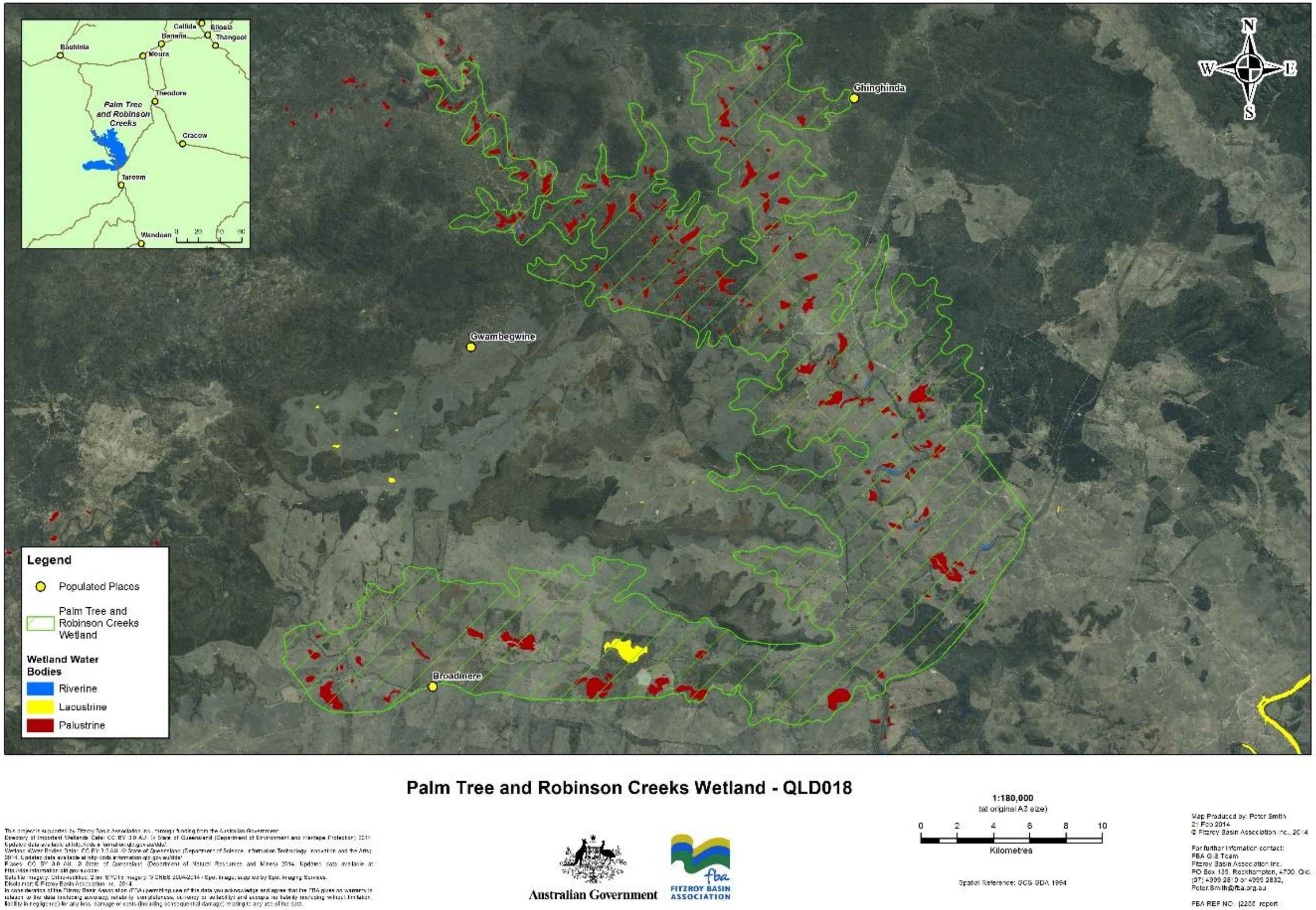

Figure 1. Project study area: Palm Tree Creek and Robinson Creek Wetlands (Source: FBA)

3.1.3 History of settlement

Explorer Ludwig Leichhardt is a central figure in the history of European settlement in the Taroom region. The 2003 local history by Judy Gale Rechner – *Taroom Shire: Pioneers, Magic Soil and Sandstone Gorges* – contains considerable detail on Leichhardt. Rechner describes how, in 1844, Leichhardt and his party of eight were the first non-indigenous men to see the Upper Dawson country. They were on a 3000 mile (4800 kilometre) journey from Jimbour on the Darling Downs to Port Essington on the coast of the Northern Territory.

Figure 2. The 'Leichhardt Tree' on Main St Taroom, March 2013

Rechner includes extracts from the diaries kept by Leichhardt and ornithologist John Gilbert in her book, which describe the country and its flora and fauna. For example, according to Leichhardt's diary they found a swamp and lake with beautiful birds on it on 14 November 1844. They also found a palm-fringed creek running into the Dawson River, which Leichhardt named Palm-Tree Creek. The next day they followed this creek for six miles, stopping near a large lagoon, which they named Roper's Lake. On 19 November 1844 Leichhardt wrote that he and his party continued:

"In a westerly direction over a level country, partly covered with reeds and fat-hens, and came to a broad and sandy creek, which turned to the south-east and south. Having crossed it, we passed several large lagoons and swamps covered with plovers and ducks; and a short mile farther came again on the creek, which now had a deep channel and a broad sandy bed lined with casuarinas and flooded-gum trees. I called this 'Robinson Creek.' At its left bank we saw a wide sheet of water, beyond which rose a range densely covered with scrub: I called them Murphy's Lake and Range."

Their diaries included a report of finding a brush turkey's nest, of seeing black swans and also a whistling duck. In both the Dawson and Robinson, fish and eels were caught to supplement their food supplies. Ornithologist John Gilbert wrote in his diary:

"If any part is finer than another, perhaps Palm Tree Creek might have the preference, for the great number of lakes and dense reed-beds on each side of the creek must render it exceedingly valuable as a summer run, and there appears country of sufficient extent to accommodate many large herds and flocks."

According to Rechner, Leichhardt's descriptions of his travels were published in newspapers: "His descriptions of pastoral lands no doubt encouraged others to travel in his footsteps. The 'Leichhardt track' was followed very quickly by squatters who eagerly settled along and beyond the explorers' route." By 1856, the town of Taroom had been established.

The 'Leichhardt Tree'– a large coolabah tree, indigenous to the Dawson River district and estimated to be about 300 years old – continues to stand proud in Taroom's main street, Yaldwyn Street (Figure 2). It is said to have been marked by Leichhardt on his journey with the inscription 'LL 1844' (Rechner 2003).

Figure 3. Plaque welcoming visitors to Taroom, March 2013

3.1.4 Land use

Today cattle grazing on pastoral leases is the dominant land use in the study area (Bastin 2008); coal mining is also a major regional economic driver (Rechner 2003).

Details of the region's early pioneering days are described in Rechner's 2003 Taroom Shire: Pioneers, Magic Soil And Sandstone Gorges:

"The early pioneers of the Taroom district ran sheep from the 1840s. In the 1870s landholders started selling their sheep in favour of cattle. By the 1890s, the stockmen and boundary riders on the Dawson cattle stations had become known as some of the finest scrub dashers and rough riders in Australia. The rough terrain of the 'Wild Dawson Country' – as it was usually called – was responsible for their skill. In the huge paddocks, often hilly and scrub covered, only expert stockmen could hope to carry out a successful muster, or trap any of the large number of brumbies roaming at will. To these men riding rough country and mustering were just part of their daily lives."

The region is known as having extremely productive land (Alexander et al 2001), explaining the title of Rechner's book. As she describes: *"Much of the Shire has magic soil. It is heavy, fertile and black."*

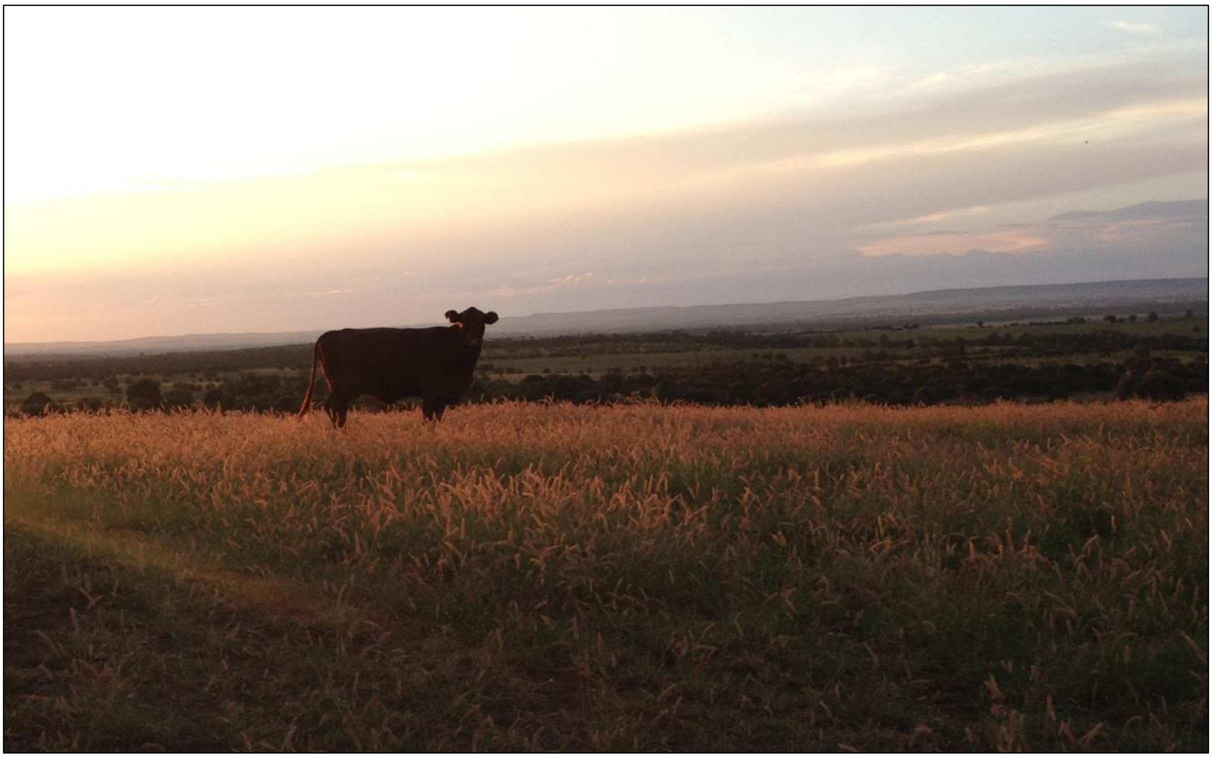

Figure 4. Typical view across the Robinson Creek catchment, March 2013

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4 Stories

This section presents edited versions of the seven interviews with Taroom locals conducted as part of the study; written in the third person as succinct stories and accompanied by photos, both new and archival.

Elgin and Ineke Hay – La Palma lagoons, Palm Tree Creek

Figure 5. Elgin and Ineke Hay on one of the La Palma wetlands, Dicks Lagoon, about 2km from the homestead, with a mass of water lilies in the background, March 1999. (Source: Elgin and Ineke Hay)

Elgin Hay does not know why it is so, but he swears that ducks have an uncanny knack for knowing when floods are on their way. For the best part of 60 years Elgin lived by the Palm Tree Creek wetlands at La Palma. One of his most vivid memories of these wetlands is how the ducks would lay their eggs a few hundred metres uphill right before a big flood came through.

"Fair dinkum – and I won't be surprised if you don't believe me – it can be dry for 12 months, then the lagoon can fill overnight and you will see little fluffy ducklings on the water the very next day," recalls Elgin.

Elgin Hay was born at La Palma in 1935 and lived there, grazing cattle, until 2002. La Palma has a number of semi-permanent open water wetlands. The Hay family did not give each of these wetlands names; they were *"just the lagoons,"* says Elgin. The one closest to their homestead was the *"house lagoon."*

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A diversity of birdlife came to the lagoons in wet times, but it is the black swans that feature strongest in Elgin's memory. Elgin and his siblings spent a lot of time as kids playing by the water. While most of the birds would keep clear, the swans were friendly and followed the children about. *"We would be mucking around in the reeds and it was easier for mum to spot the swans to know where we were,"* says Elgin.

Elgin recalls some of the wetlands being more popular with the swans than others. Once, he saw a group of about 300 black swans gathered on the house lagoon. Later, when Elgin and his wife Ineke had children, he remembers one of the kids coming home and saying he had seen *"nature at its best today."* When asked why, his boy told a story of seeing two adult swans protecting their young from a hawk. The hawk had been flying around eyeing off the cygnets for its lunch. Whenever the predator flew near, the swans would call the cygnets close and stretch out their wings to protect them.

Elgin and Ineke remember another occasion when the children befriended a particular swan that was moulting and so could not fly. The children *"ran it down"*, caught it and brought it home to play with on the lawn. Their son, nine years old at the time, carried the body of the swan while their daughter, ten years old, 'carried' the swan's neck. Elgin made them take it back to the lagoon. For some time following, the kids went back to the lagoon each day, picked up their friend, *"Swanny,"* and brought it back to the house, then took it back to the lagoon at the end of the day. Elgin remembers the swan being quite relaxed about this routine: *"It did not run away again after the first time they ran it down, it just let them pick it up and carry it around,"* he recalls.

Along with the swans, Elgin has memories of the water lilies. While the La Palma house lagoon was virtually lily free, others were crowded with them. Elgin describes a wetland at Bloomfield, the property adjacent to La Palma, as having a high rocky hill just beside it. He says if you stand on top of that hill at the right time – when the water lilies are thick on the water, and the sun and humidity are just so – all you will see is a blue haze.

Elgin was concerned about the impact of the big 'Millennium' drought on the wetland vegetation. When it was dry he had seen feral pigs digging up the water lily bulbs, so when the lagoons filled up again with the floods of 2010/11 Elgin was relieved to see the lilies in bloom once more.

Figure 6. Swans on 'The House Swamp', one of the many wetlands on the La Palma property. (Source: Elgin and Ineke Hay)

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In 2002 Elgin and Ineke retired, leaving their son Stewart to manage La Palma, and they now live west of Taroom in Greenoaks. Ineke is delighted to see a White Bellied Sea Eagle still nests yearly at one of the reedy grassy swamps on the property. She says they also get sea gulls at the swamps after a few days of a south-westerly wind and they wonder if it is those winds that bring them from Lake Eyre toward the Pacific Ocean.

It has been more than a decade since Elgin and Ineke have lived with swans in their backyard, but they still speak of them with fondness. *"They are one of the most amazing birds; they are attracted to humans for company, and are more likely to swim toward you than to swim away,"* explains Elgin. He expresses his admiration for the monogamous relationships among swans, *"They pair for life."*

In speaking with Elgin and Ineke about their memories of life on La Palma, you get the sense they know well what it is to be devoted to something dear.

John Hay – La Palma lagoons, Palm Tree Creek

Figure 7. John Hay outside the Historical Society of Taroom where he serves as President, March 2013.

In John Hay's experience it takes quite a bit to prove you are a true local. Despite having lived in the Taroom region all his life, along with five generations of the Hay family, he found his credentials brought into question one day when he admitted that he was actually born in a Brisbane hospital, owing to his mother's ill-health at the time. *"Strewth! There I was thinking you were a local boy,"* the old-timer said. According to John, this fellow was quite put out.

John grew up on a property on the Palm Tree Creek called La Palma. While it has been a touch over 50 years since he has lived on the Palm Tree, John has fond memories; many of which relate to the creek and several wetlands on La Palma. The wetlands with a range of names are known to the family as swamps, lagoons and billabongs.

In John's experience when the creek flooded, it flooded quickly. *"You'd go mustering in the morning and by the afternoon the creek would be halfway up the bank because of a storm somewhere at the top of the creek,"* he explains. *"That was just part of life – swimming with horses!"*

John considers himself lucky that he has witnessed something quite rare. Once, in about December 1950, he saw the dry Palm Tree Creek filling with floodwater before his eyes. *"There was a huge pile of logs rumbling down the creek being pushed ahead of a wall of water, without a drop in front."* He has also learned over the years that when the ants build up new sections on their anthills and mother ducks take their ducklings from higher ground down to the water, it will be sure to rain in the next few days; *"They know the water is coming."*

During big floods John recalls there being flying foxes rigged up over the creek in days gone by, to get people and supplies across. John's father, Charles Alexander Hay, told stories about the big flood of 1928 in the Palm Tree Creek. The flood came right through the La Palma homestead and left everything covered in mud. Father Hay was charged 30 shillings, quite a sum at the time, to have his fob watch cleaned of mud and put back into working order again.

There were also very dry times. John recalls making sand troughs to draw water as a means to survive when the creek ran dry, as it was only wet for about nine months of the year. A spear point pipe or a log with a rail fence would be rigged up to harvest the water level that was *"about elbow deep"* below the sand.

John remembers the fishing being good when he was a kid. He knows because his dad was a keen fisherman who would have a fishing rod stashed in the paddocks and in the bush near every good water hole. *"He might be out working and he'd think 'Ah, it's about time to knock off and go have a fish',"* recalls John.

On one occasion when his dad was fishing he coughed, causing his false teeth to pop out of his mouth and into the creek. The following day, John and his brothers where tasked with the job of diving into the cold water to retrieve the plate; to no avail. *"We told him that a Jewfish was swimming about grinning, smiling nicely with them on."*

In his travels interstate John has noted a number of other wetlands, and has come to realise that those along the Palm Tree and Robinson creeks are quite unique. John remembers sleeping on the verandah of the old house at La Palma with the sounds of the swamp in the background. The frogs made quite a racket; *"One frog had a call that sounded like 'walk in, knee deep; walk in, knee deep,'"* he laughs. But it was the sound of the swans and ducks on the water at night that John loved the most. He says that, since moving away *"it's the sounds I've missed all my life."*

Figure 8. John Hay's father's watch (Source: John Hay)

Figure 9. In days gone by duck shooting was a big social occasion at the end of the winters on the swamps of the Palm Tree Creek. John's father, Charles Hay, is pictured second from right (Source: John Hay)

Figure 10. Swamp in front of the La Palma homestead in the mid 1950's. (Source: John Hay)

Figure 11. Taking a dip in one of the Palm Tree Creek swamps, known to the family as the La Palma Billabong (Source: John Hay)

Ian Williams – Milky Swamp, Robinson Creek

Figure 12. Ian Williams by 'Milky Swamp', March 2013

Ian Williams reckons building a holiday place by 'Milky Swamp', where people could relax and paddle about on the water, would be pretty nice; *"It's so peaceful,"* says Ian. *"You want to come here early in the morning when all the birds are talking."*

Milky Swamp is the largest of a cluster of wetlands on the Sandstone Creek – a tributary of the Robinson Creek –that flows through 'Broadmere'; the 7,000-hectare cattle grazing property owned by Ian Williams and his wife Ros. Ian came to Broadmere with his parents at 16 years of age, off another property inland from Mackay.

According to Ian, the swamp gets water in it most years from catchment runoff. When full, it is about two metres deep and seven kilometres around. After being dry for about a decade, the countryside and swamp is currently the *"best you'll ever see it"* according to Ian, thanks to the good rains of the past few years. The grass and reeds are looking lush, blue lilies adorn the water and dragonflies are busy flitting about.

Black Swans, Brolgas and Black-necked Storks[1] are amongst the birds Ian sees at Milky Swamp, along with a variety of duck, egret, shag and water hen species. Ian does not claim to know much about birds, and is not sure where they all go when Milky Swamp is dry, *"But as soon as the swamp is full there will be Pelicans and everything here,"* says Ian. The frogs make their presence known too: *"When it first fills up the sound almost drives you mad; it's an absolute din!"*

Ian says that the conditions are so good this season that the waterbirds have had two rounds of young. *"Each duck usually has eight or ten little ones,"* observes Ian *"and they have had two lots this year."*

Figure 13. Eagles nest, Milky Swamp, March 2013

At one stage a family friend built a bird hide on the swamp. This friend would go into the hide before daylight and take photos of the birds as the sun rose across the swamp. *"He took some beautiful photos"* recalls Ian.

In Ian's experience the waterbirds are pretty comfortable around people. Ducks nest right up on the edge of the water and the swans will often come up close. *"They gobble a bit like turkeys,"* describes Ian. *"And when you yell at them they answer you; they hoot back."* The birds don't seem to mind the cattle much either: *"You'll see birds sitting on the backs of cattle."*

[1] Black-necked Stocks are often referred to as 'Jabiru', which is a similar looking bird found in the Americas

Ian and Ros have three boys, all adults now. Ros is a good horse rider and taught the boys to ride as kids. They helped muster from a very young age, as well as helping in the yards. *"They spent a lot of time on the water,"* recalls Ian. He would take them fishing on the Sandstone and on Robinson Creeks, where there was a big water hole. They had a canoe and even a little sailing boat that they would take onto Milky Swamp with the neighbours' kids.

Ros and Ian's son, Shane, is back home on the farm after going away to study agricultural business at university. He lives in the original Broadmere homestead where Ian's parents once lived, with his wife, a school teacher. With the recent arrival of their baby boy it might not be long before a fourth generation of the Williams family will be out enjoying the tranquillity of Milky Swamp.

Malcolm and Ann McIntyre – Wainui Swamp, Robinson Creek

Figure 14. Wainui Swamp, March 2013

In 1981, when Malcolm and Ann McIntyre moved to Wainui on the Robinson Creek, it was a novelty to see a car pass by. *"There was no-one around,"* recalls Malcolm. *"Ann would go to town about once a fortnight, and we would get mail once a week."*

While there may not have been many people about during their early years in the area, the McIntyres have fond memories of many festive social occasions – often centred on the Robinson Creek. Every New Years Day and Good Friday they would host picnic gatherings on a bend of the creek where there was a sandy beach. They would set up a large lean-to and a flying fox across the creek and make a day of it. *"All the neighbours up and down the creek, you just ask them, they seriously loved it,"* recalls Ann *"Everyone swam and played in the water, even the adults."*

It was two years after their arrival, in 1983, that the McIntyres first saw the Robinson flood; a *"real eye opener,"* says Malcolm.

They now know that once the Robinson Creek gets to three-quarters of a bank full, it flows across a gully to fill the Wainui swamp. The swamp was dry when they first arrived. The elderly lady who owned the property before them said she had only seen it dry twice.

The gully that connects Robinson Creek to the Wainui swamp is known as *"Belly Buster"*. The previous owner of the property explained to Malcolm that the name originated from when cars used to get bogged in it when it was wet, and *"you would bust your belly trying to push them out."* In the McIntyre's experience the 300 acre swamp can fill overnight. *"You can go to bed at night and wake up in the morning and it's just a sea of water."*

As soon as there is water, the birds come. *"It goes from nothing, to being thick with birdlife – pelicans, swans and all different types of ducks,"* says Malcolm. Ann recalls often seeing Brolgas dance on the nearby swamp as she drove their two children to the school bus stop. The McIntyres can also see Lake Murphy from their home when it is full. *"Often, you'll see the pelicans; they'll do a great big loop off the lake and they come back later on in the day,"* explains Malcolm.

Malcolm and their neighbour Ian Williams bought a little sail boat one year, to take out on the swamp with their children. Sometimes they would catch fish on the swamp – Jewfish, Yellowbelly, catfish, and eels. Malcolm also remembers there being plenty of turtles in the water, and that they would eat the bait off the fishing lines. The children thought the sail boat was *"the best thing ever,"* says Ann. But before they had a chance to learn to sail it themselves, the swamp dried up and stayed dry for over a decade; *"So they took the hulls off and put bicycle wheels on it instead."*

Malcolm and Ann noticed the Robinson Creek change significantly with the big floods of 2010 and 2011. Creekbanks caved in and trees fell across the creek; there is now heavy erosion all along the banks, muddying the water and sand. Malcolm puts this down to the volume and velocity of these floods being much greater than previous floods. To illustrate, he points out that the picnic tables at Lake Murphy ended up under four feet of water and that many of them were washed out by 30 yards: *"These are tables that are so heavy it would take four grown men to carry them back into place."*

Today, after over 30 years at Wainui, it is not such a novelty for the McIntyres to see a car drive past. There is more activity in the area, and their road is much busier.

Figure 15. Cattle at Wainui, March 2013

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Figure 16. 2010 flood level engraving on the McIntyre's engine shed wall, March 2013

Adam and Dot Clark – Lake Nunbank, Robinson Creek

Figure 17. Adam and Dot Clark, May 2013 (Source: Adam and Dot Clark)

When asked to describe what growing up by Lake Nunbank was like Adam Clark does not hold back: *"We had the most glorious childhood you could ever imagine,"* he says, *"We had thousands upon thousands of acres of country and beautiful wetlands."*

The Clark family came to the Nunbank property on the Robinson Creek in 1939, when Adam was six years old, and set themselves up grazing sheep. Adam and his two brothers were schooled by correspondence until age ten, with their lessons delivered and sent off once a week on a pack horse mailman.

Adam remembers sleeping on the veranda at Nunbank and waking up to the sound of birds. His wife, Dot, says Adam and his brothers had a very lenient mother: *"She let them pack their lunch and smoko and take off all day with the dog and a half-axe."* They built cubbies and explored; watching nature, chasing goannas, stealing swans eggs off the lake and learning to follow tracks. Their father built them a tin canoe and they could all swim like fish. *"Why we didn't grow scales I don't know because we just lived in the water,"* laughs Adam.

When Lake Nunbank is full it stretches across 1000 acres; 600 acres of open water and 400 acres of reeds and mud. Over his 74 years of watching the lake, Adam has seen it permanently full for seven years and dry for five. Large cracks open up in the soil when the lake has been dry for 12 months or more. Adam recalls these cracks getting up to five or six feet deep and lambs falling in. When the 1946 drought broke, early in 1947, the flood came up suddenly. *"We had a cloud burst and 'whoosh' down came the water,"* recalls Adam. Several weeks later, Adam and his brothers were out canoeing on the freshly filled lake and noticed large bubbles rising to the surface. They raced home to describe what they had seen. Rather than tell tales of mythical bunyips lurking below the surface, their father explained that silt that had washed in and sealed the top of the cracks but had not filled them to the bottom, so the air trapped beneath eventually had to get out.

Figure 18. Adam Clark in 1940, aged 7, with his pet lamb 'Lily'. Photo taken to submit to his correspondence school magazine when in Grade 2 (Source: Adam and Dot Clark)

Dot grew up on a farm in Dalby and met Adam at an *"all schools dance"* in Warwick when they were both at boarding school. In the year they were married, 1954, there was a big flood in the Robinson. Dot remembers the water coming right up close to the Nunbank shearing shed.

When Lake Nunbank was full there would sometimes be thick fog till 11am and the doilies would be green with mildew. Dot recalls *"poor Gran Clark"* filling her vases with flowers in the morning only to have frogs getting into them at night and tossing all the flowers out. It used to drive her mad so she once gave her eldest grandson the job of frog control. He collected a whole bucket of frogs and for his efforts she rewarded him with a green tricycle.

When Lake Nunbank has water, it is full of waterbirds. *"They would make such a noise settling at night,"* recalls Dot. Adam has seen up to 70 swan nests on Lake Nunbank. He says it is good for the swans to nest on because it has the right vegetation, with lots of reeds. The Clarks never allowed duck hunting on the lake *"mum put her foot down,"* explains Adam.

The Clarks have seen the wetlands change over the years. *"In a nutshell, they are getting bigger and shallower all the way down the Robinson,"* explains Adam. He says the creek is carrying a lot more sediment these days, *"It's slowly silting up the outlets."*

It does not take much time spent with the Clarks to appreciate how much they love this country. *"We've all had a lot of fun on it,"* says Adam *"And the other interesting thing is we've all made an adequate income from the floodplains. It's very productive land provided you manage it carefully."* The Clark family motto is *"Live your life as though you are going to die tomorrow, but farm your land as though you are going to live forever."*

Figure 19. A couple of photos from the Clark family album, left: Lake Nunbank 1949; right: Dot Clark in 1954, with the family dogs, Lake Nunbank in background. (Source: Adam and Dot Clark)

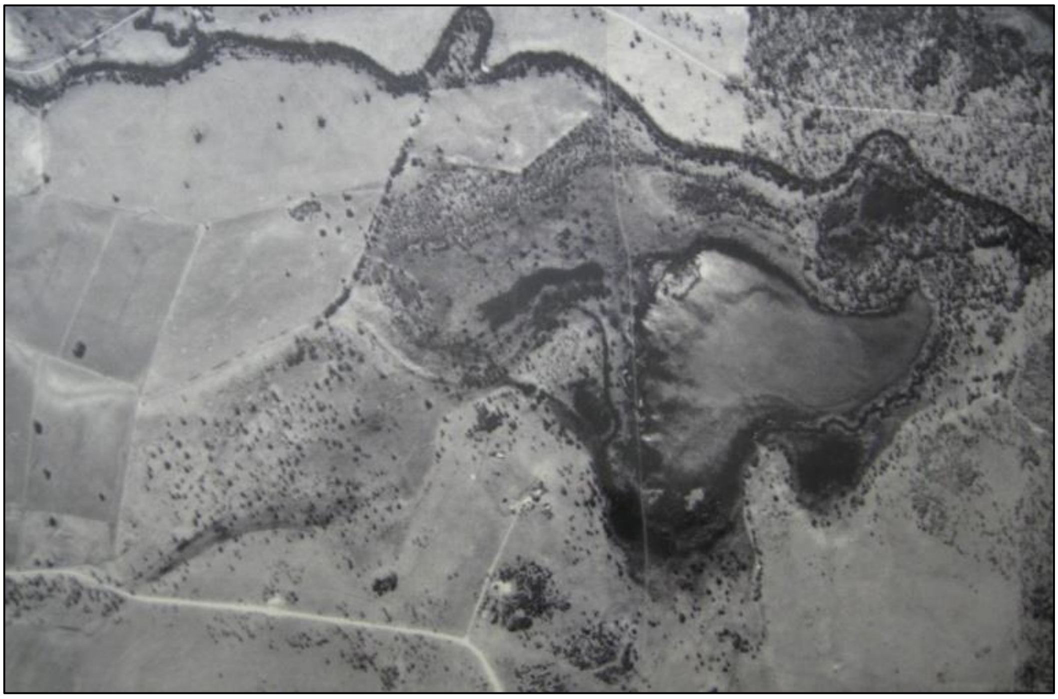

Figure 20. Lake Nunbank and homestead from above, August 1990. (Source: Adam and Dot Clark – segment of an aerial photograph presented to the Clark Family in June 1993 by the Taroom Shire LandCare Committee).

Figure 21. Clark Family picnic by Lake Nunbank, 1995 (Source: Adam and Dot Clark)

Figure 22. One of the biggest Coolibah trees Adam has seen: "He's 22 foot 10 inches round at shoulder height and note the Toyota parked underneath" – a pride of the Nunbank property (Source: Adam and Dot Clark)

Tom and Patsy Poole – Lake Nunbank, Robinson Creek

Figure 23. Tom and Patsy Poole, March 2013

It was a lack of interest in classroom learning that led Tom Poole to the Taroom region as a young lad: *"I wasn't a very good scholar, but I was keen on horses,"* he recalls. Tom left school and his hometown of Melbourne and, through a family connection, ended up in Taroom in 1948 helping to deal cattle.

It was then that Tom began learning about life in Brigalow Belt country.

Tom remembers people farming the flats along Robinson Creek in the early days. Cattle herders and shepherds camps were dotted about the country, amongst the Box Gums and Coolibah trees. Many started off grazing sheep but a change in the price of wool caused a switch to cattle grazing.

From 1948 – 1960 Tom was based at the Clark family's property, Nunbank, on the Robinson Creek. He married Patsy, a local girl in 1955 and they set themselves up as share farmers at Nunbank. Lake Nunbank was full that year and there was a big flood in 1956: *"Water came within about 20 foot of our back door,"* recalls Tom, *"I remember there being swans swimming in the backyard,"* adds Patsy. Tom and Patsy started their family at Nunbank and lived a life of self sufficiency, when all the washing was done by hand or in the copper and food was stored in a kerosene fridge. Tom recalls frosty early morning starts; rising at 4am and taking the *"nighthorse*" to round up the other horses.

They worked hard, but also knew how to relax. *"You'd work your Monday through to Saturday and come Saturday afternoon you had your free time,"* describes Tom.

Often, this free time was spent fishing and swimming in the Robinson Creek and Lake Nunbank. Tom and Patsy recall *"big lovely waterholes"* in the creek where they could catch fish; mostly perch, eel and Jewfish. They saw the wetlands change from flood to flood. Over time, so much sand would wash down with a flood that it completely filled up many of the old fishing holes. Tom and Patsy say fishing is still good in many places today, especially after floods.

Figure 24. Lake Nunbank, early 1950's (Source: Tom Poole)

Floods may have been good for fishing, but they also threw up challenges. Tom remembers droving cattle into the sale yards once and discovering their path cut off by sudden flood waters on the Palm Tree creek side of town. He had to turn the cattle around and drove them back home again. On another occasion, when a flood was coming up at Nunbank, Tom was tasked with helping a pregnant woman who was camped in a farming area with her husband out of town lining up more work. Tom had to get her to the homestead in the middle of the night, as she was about to give birth. Tom felt for the horse, having to pull the sulky through the mud and gullies; rain pouring overhead. *"Poor old horse, it was hard work".*

More recently, during the 2010 flood, Tom and Patsy's daughter found herself stranded on the roof of her house at the top of the Robinson Creek. With the whole region inundated, help was hard to come by. Luckily, Adam Clark's son had his own helicopter and he was able to fly it out from Roma to rescue her.

Tom and Patsy now live in town. On a recent drive out of Taroom into the surrounding countryside Tom was impressed with how good the area is looking after the past few years of good rainfall*: "It is* *the best it's been in a long time; just beautiful."* Tom saw green grass, full lakes and Black Swans on nests and said to himself: *"Gee, I love this country."*

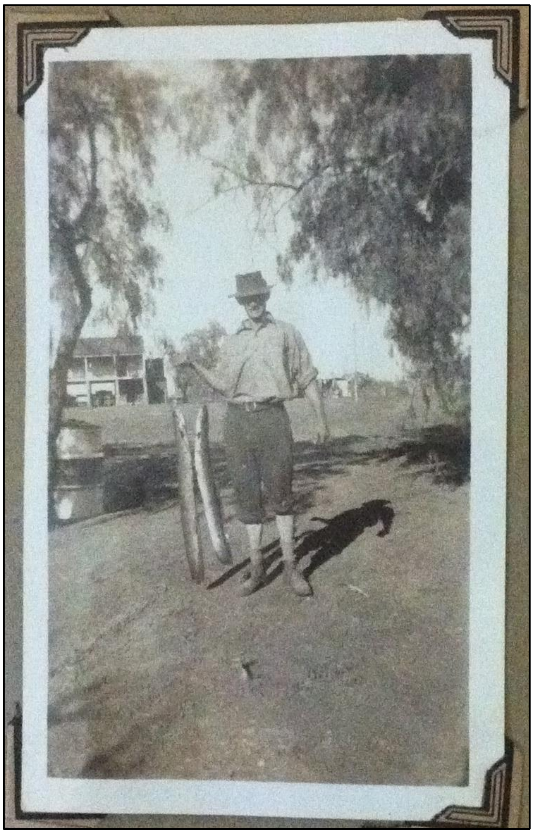

Figure 25. Left: Tom Poole, March 2013, looking through his old photo album; Right: Adam Clark's father, Barney, with a catch of eels. (Source: Tom Poole)

The Kerlin siblings (Carmel, Pat and Tony) – Nine Mile Swamp, Robinson Creek

Figure 26. The Kerlin siblings and partners in March 2013, left to right: Dianne Kerlin (Tony's wife), Tony Kerlin, Carmel Lawton (nee Kerlin), Pat Welsh (nee Kerlin) and Lawrie Welsh (Pat's husband).

There was a water hole on the Robinson Creek so deep the Kerlin siblings – Tony, Pat and Carmel – were forbidden to go near it as children. *"It was a beauty," recalls Tony; so deep "we never made it to the bottom."*

Get these siblings together to talk about life by the Robinson and Palm Tree Creeks and their stories will jump excitedly from one location to the next. They have memories of watching Brolgas perform their mating dance on 'Broadmere' near the Robinson, particularly around Easter time; along with tales of chasing uninvited duck hunters from Brisbane off the swamp at 'Huntington' on the Palm Tree. Swimming and fishing in the Robinson Creek was a favourite pastime for them as kids; they also spent time at the nearby Lake Nunbank with the Clark family. *"Sunday was the rest day for our mum and dad and it was always a fishing day,"* recalls Pat. Stories of the region's plentiful water birds feature strongly in their memories, such as describing the sound of Pelicans flapping along the water and the sight of them getting organised into mobs of 20 to 30 to take-off in an orderly way, following one leader, as though they were in 'drills'. *"It was beautiful to watch,"* says Pat.

But it is Nine Mile Swamp that they know best. This was the biggest of a series of wetlands on 'Verbena Park', the property they grew up on by the Robinson Creek. The Kerlin family moved there in 1954, off another property a little further south called 'Bottle Tree.' *"Dad used to farm cattle and he relied on the swamp as a water source,"* explains Tony.

Nine Mile Swamp is connected to the Robinson Creek via the Nine Mile Gully. *"When the creek overflows it fills the swamp, which is usually when the creek is three-quarters full,"* says Tony. He only recalls seeing Nine Mile Swamp really full about three times in his life, but it was rarely dry either. Pat remembers it as being *"a lovely swamp"*; home to Black Swans and Pelicans; she preferred to call it a 'lagoon'; *"it sounds nicer,"* she says.

Figure 27. An old photograph of the Kerlin siblings as children (Source: Pat Welsh)

The siblings recall there being plenty of waterbirds on Nile Mile Swamp when it was wet. The house was not far uphill from the swamp, so when it was full they would hear the birds at night. They also have fond memories of their family hosting New Years Day parties by the swamp, when all the neighbours would come for a picnic get-together. There would be fishing, boating, and some people would go off shooting ducks.

Having been in the region all their lives, the Kerlin siblings have seen plenty of change. Pat recalls Verbena Park being cut off from town for three weeks during the big flood of 1956. In terms of the creeks, one of the major changes they have seen is increased siltation. That once-forbidden waterhole on the Robinson Creek is no longer a danger to children: it has completely filled up with silt, along with many of the other deep waterholes. While some change may be permanent, in other cases it appears not. Tony reports seeing some Plain Turkeys recently; something he had not seen *"for ages."* He was pretty excited.

Figure 28. Swimming in the Robinson Creek in the 1950s. (Source: Pat Welsh)

Figure 29. View of Nine Mile Swamp from the Bottle Tree Park property in March 2013, just uphill from the house. It is the biggest it has ever been as it now has artificially raised banks.

Figure 30. A young *Livistona* palm (the name-sake of the Palm Tree Creek) in the front yard of the house at Bottle Tree Park

Figure 31. Black swans in the overflow from Nine Mile Swamp in flood, December 2010 (Source: Dianne Kerlin, wife of Tony)

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FITZROY BASIN ASSOCIATION

Guidelines for Management

FITZROY BASIN ASSOCIATION

Our country, Our future

Guidelines for Management of the Palm Tree & Robinson Creek Wetlands

July 2014

Prepared and authored by Roger Jaensch for Fitzroy Basin Association Inc.

Australian Government

Santos GLNG Project

The development of this report was supported by the Fitzroy Basin Association Incorporated (FBA) through funding from the Australian Government and Santos GLNG.

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Summary

The Palm Tree and Robinson Creek Wetlands are an aggregation of more than 155 floodplain swamps, lakes and creeks in the Dawson River catchment, Fitzroy Basin, central Queensland. Listed in the Australian Wetlands Database, it is considered to be a nationally-important wetland complex, particularly because it is representative of wetland types of the Brigalow Belt South biogeographic region. Arguably, Palm Tree and Robinson Creek Wetlands is a unique aggregation, not only in this region but also at broader scale, in terms of its dense cluster of abundant stream-fed waterbodies lying in the upper catchment of a river basin. It is almost entirely in private tenure under cattle grazing enterprises apart from a small Conservation Park at Lake Murphy.

In 2013, the Fitzroy Basin Association with funding support from the Australian Government and Santos GLNG, conducted an assessment of the functioning, values and condition of the Wetlands through six investigations: flora; birdlife; aquatic ecology; hydrology; terrestrial vertebrate fauna; and local perspectives. (Standalone reports are available for each study.) This work was led by expert investigators but relied greatly on the cooperation and knowledge of landholders. It provided baseline information for development of management guidelines for Palm Tree and Robinson Creek Wetlands, which is the subject of the present document.

The considerable importance of the Palm Tree and Robinson Creek Wetlands can be described in more detail in terms of ecosystem services that the site provides to human communities, as well as its biodiversity values. These ecosystem services include provision of fodder and water for farm livestock, recreation sites, retention of floodwater, and indigenous and other heritage. From a biodiversity perspective, the Wetlands provide refuge and breeding habitats for rich and abundant communities of native waterbirds and fishes and support diverse communities of aquatic plants; dry-land habitats within the aggregation harbour additional species. Further study may reveal additional values.

Primary among threats to the Wetlands' services and values are further sedimentation of channels and basins, and invasive plants (notably lippia) and feral animals; loss of water supply through possible future dams or water harvesting is a potential future threat. Additional threats include barriers to connectivity, loss of or change to wetland vegetation and biota caused by unsustainable grazing pressure from livestock, potential accelerated drawdown resulting from future interference with regional groundwater tables, and community-wide lack of awareness of the Wetlands' ecosystem services and biodiversity values.

Responses aimed at mitigating threats to the ecosystem services and biodiversity values of the Palm Tree and Robinson Creek Wetlands are described in the present document as a set of recommended management guidelines. In each case, an explanation of the issues is followed by suggested actions and an indicative list of stakeholders or parties that might participate in implementation. The responses are grouped into four categories as follows:

Water supply:

- Maintain Palm Tree Creek and Robinson Creek as free-flowing streams
- Remove barriers to connectivity between supply creeks and swamps/lakes and ensure that no increased drainage of wetlands occurs
- Minimise sedimentation in the wetlands
- Prevent the possible contribution of mining or gas extraction to drawdown in wetlands

Livelihoods:

- Implement appropriate grazing regimes for wetlands
- Fence to control access of livestock to wetlands
- Establish off-wetland watering points

Biodiversity:

- Control invasive plant and animal species
- Manage trees in and beside wetlands to optimise benefits for biodiversity

Knowledge:

- Promote the values and wise use of the site's wetlands by using suitable media and methods and expand the knowledge base.

The document concludes with recommended priority actions from among the suggested guidelines, and remarks on a strategy for monitoring and review of the guidelines.

Nymphoides crenata (wavy marshwort) Photo by C. Pennay

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Glossary and Acronyms

DCCA	Dawson Catchment Coordinating Association (DCCA) http://www.dawsoncatchment.org/
DIWA	Directory of Important Wetlands in Australia http://www.environment.gov.au/topics/water/water-our-environment/wetlands/australian-wetlands-database/directory-important
ecosystem services	the benefits provided to humans through the transformations of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services e.g. clean air, water, and food. http://www.environment.gov.au/system/files/resources/b53e6002-4ea7-4108-acc8-40fff488bab7/files/ecosystem-services.pdf
EHP	Department of Environment & Heritage Protection https://www.ehp.qld.gov.au/
FBA	Fitzroy Basin Association http://www.fba.org.au/
NRM	natural resource management
palustrine, lacustrine	broad types of wetland equating generally to swamps (palustrine) and lakes (lacustrine), with areas of water less than 8 ha being included as palustrine. http://wetlandinfo.ehp.qld.gov.au/wetlands/what-are-wetlands/definitions-classification/system-definitions.html
PTRCW	Palm Tree and Robinson Creek Wetlands; the site as listed in the Australian Wetlands Database http://www.environment.gov.au/topics/water/water-our-environment/wetlands/australian-wetlands-database
RE	Regional Ecosystem: a vegetation community in a bioregion, which is consistently associated with a particular combination of geology, landform and soil (Sattler and Williams 1999) http://www.ehp.qld.gov.au/ecosystems/biodiversity/re_introduction.html
WPSQ	Wildlife Preservation Society of Queensland http://www.wildlife.org.au/

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1 Background

1.1 Location and features of the Wetlands

1.1.1 Overview of the site

The Palm Tree and Robinson Creek Wetlands (PTRCW) is an aggregation of wetlands in the Dawson River catchment, Fitzroy Basin, central Queensland. The site is 28 kilometres north of Taroom with coordinates 25^{o} 23' S, 149^{o} 47' E (Fig. 1). It extends approximately 44 kilometres in a north-west to south-east orientation and the area enclosed by its boundary is 50,233 hectares (DoE 2014a).

The site is mainly underlain by sandstone, with some areas of shale. The land profile is steep to moderately undulating in upstream parts of the site but grades downstream into floodplain lowlands (DoE 2014a). There are significant differences between the Palm Tree Creek component, which has a narrow floodplain and sandier soils, and the Robinson Creek component, which has a broad floodplain and predominantly clay soils (Alluvium Consulting 2014a).

Principal wetland features of the PTRCW are: the channels of Palm Tree Creek and of Robinson Creek, which meet in the south-east corner of the site; and more than 155 off-river wetlands – swamps and lakes – that are closely associated with these dominant creeks and their minor tributaries (Fig. 1). This high density of wetlands gives a distinctive character to the PTRCW.

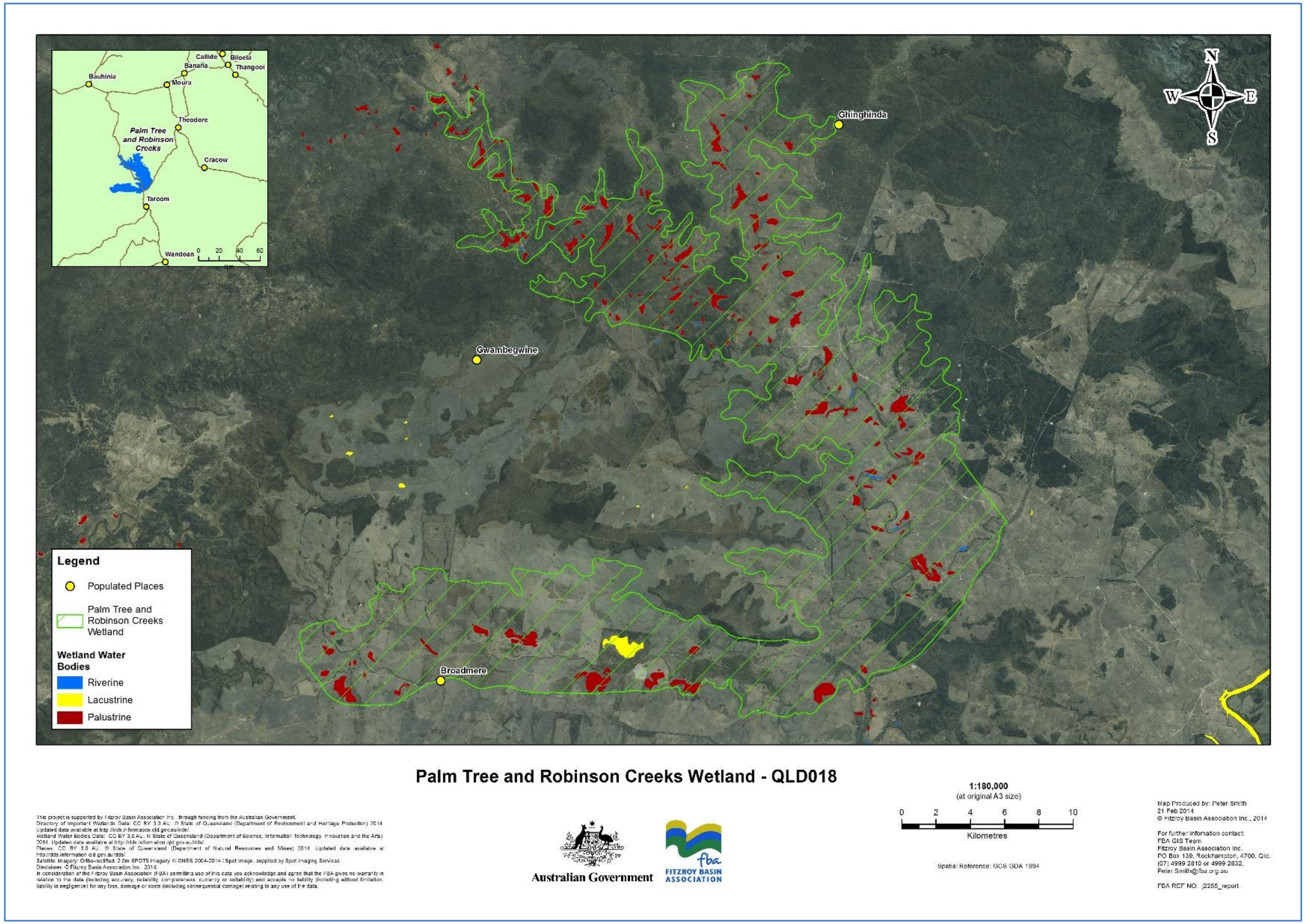
Wetland mapping produced by the Queensland Government (DEHP 2014a) shows the extent of creek/channel wetlands (classed as riverine) in the PTRCW and classifies all of the off-river wetlands as palustrine (swamps; dominated by emergent vegetation), except Lake Murphy, which is lacustrine (Fig. 1). The methodology generally excluded wetlands less than 1.0 ha in area or less than 35 m wide and bodies of open water less than 8 ha in area were classed as palustrine. The mapping shows 134 off-river wetlands associated with Palm Tree Creek (5 exceeding 50 ha) and 20 associated with Robinson Creek (7 exceeding 50 ha); many wetlands less than 1.0 ha have not been mapped. The total area of mapped wetland in the PTRCW is about 2500 ha (DEHP 2014a); actual area of inundation in the swamps and lakes can vary from less than 150 ha in severe drought to around 9000 ha in extreme wet events (Alluvium Consulting 2014a).

A full explanation for the abundant wetlands at this location is not yet possible. However, it seems that swamps and lakes formed at the outlets of small gullies and drainage lines as a result of natural levees that impeded flow onward to the more substantial nearby creeks (Halford & Fensham 2014).

1.1.2 Hydrology: water supply and connections

Annual rainfall in the Taroom area is in the range 600-700 mm and mostly falls from December to March (DoE 2014a). The swamps and lakes gain significant water supply from local catchments, especially in upper Palm Tree Creek, but rarely fill without a major contribution from the relevant

Figure 1: Location and wetland types of the Palm Tree & Robinson Creek Wetlands



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major creek. Inflows from Robinson Creek tend to occur once its flows are at three-quarters of riverbank height. About half of the wetlands, mainly in lower parts of the PTRCW site, receive riverine inflows as often as about once every year on average, and most of the PTRCW are fully flooded about once every 10 years on average (based on Average Recurrence Interval: Alluvium Consulting 2014b). Floods run most quickly in Robinson Creek, which has a total catchment of 1840 km^2, and slower in Palm Tree Creek, which has a total catchment of 3230 km^2 (Alluvium Consulting 2014b).

The off-river wetlands are usually less than 2 m deep except in very wet years; most are dry for several months each year and may be dry for several years during drought (Alluvium Consulting 2014a). Lake Murphy, covering 290 ha, is sometimes considered semi-permanent though it was close to totally dry when inspected by the author in January 2014.

1.1.3 Vegetation

Much of the site was cleared of trees following European settlement. Apart from on some upland areas, remnant vegetation in the PTRCW site commonly is confined to wetlands, especially in watercourses and swamps and around the perimeter of lakes. Mapping of remnant vegetation maintained by the Queensland Government (DEHP 2014b) shows several regional ecosystems (REs) within the boundaries of the PTRCW, some having been mapped as mixes of more than one RE. Swamps and lakes of the PTRCW are assigned to one RE (11.3.27), which has sub-types based on characteristics of wetland vegetation. The vegetation of these wetlands has also been sub-divided at a more detailed level according to several quantified parameters, by Halford & Fensham (2014).

Forest red gum *Eucalyptus tereticornis*, river red gum *E. camaldulensis* and coolibah *E. coolabah* are common elements of woodland associated with the PTRCW wetlands. Some riverine wetlands within the site support stands of Dawson fan palm *Livistona nitida* (Fig. 2), which is the origin of the name of Palm Tree Creek. Sedges, grasses and aquatic plants of the wetlands are described by Halford & Fensham (2014); common elements include: eelgrass *Vallisneria nana* (submerged); water lilies *Nymphaea* spp., water primrose *Ludwigia peploides* and spiny mudgrass *Pseudoraphis spinescens* (floating); Sesbania pea *Sesbania cannabina* thickets and reed-like spike rushes *Eleocharis* spp. (Fig. 3) (erect emergent); also water couch *Paspalum distichum* and nardoo *Marsilea* spp.

Figure 2: Dawson fan palms on Palm Tree Creek.

Photo by R. Jaensch

Figure 3: A wetland with fringing beds of ribbed spike-rush *Eleocharis plana*

Photo by J. Halford

1.1.4 Land use

Occupation of this country by indigenous Australians is witnessed by several visible aspects of remaining Aboriginal heritage but remains to be fully documented. Europeans settled in the area about 170 years ago and established grazing enterprises over most of the country. Cattle grazing persists as the dominant form of land use. One conservation reserve exists within the PTRCW: Lake Murphy Conservation Park (550 ha). Mining and coal seam gas industries are expanding in the region and are expected to become more widespread in the future.

1.2 Origins of the project

PTRCW is listed in the Australian Wetlands Database, Directory of Important Wetlands in Australia (DIWA: DoE 2014a) because it is considered to be a nationally-important wetland complex, particularly because it includes representative examples of wetland types of the Brigalow Belt South biogeographic region (see section 2.3, below). This status is a reason for the focus of FBA and the project funders on this site, coupled with concerns raised by the local community in connection with possible impacts on natural resources from expansion of major extractive industries in the region.

In 2013, the Fitzroy Basin Association conducted an assessment of the functioning, values and condition of the PTRCW through a series of field investigations, with a view to better understanding and managing this important wetland aggregation. Funding was provided by the Australian Government and Santos GLNG. Principal subject and authorship of each study were:

- Aquatic ecology – Alluvium Consulting (2014a)
- Hydrology – Alluvium Consulting (2014b)
- Local Perspectives – Alluvium Consulting (2014c)
- Flora – Halford & Fensham (2014)
- Birdlife – Briggs (2014)
- Terrestrial vertebrate fauna – FaunaTrack (2014)

This work was led by expert investigators but relied greatly on the cooperation and knowledge of landholders. It provided baseline information for several other publications including the present document on management guidelines for the PTRCW.

1.3 Objectives and audience of the guidelines

Broadly speaking, the objectives of the guidelines in this document are to raise awareness of ecosystem services of the PTRCW and increase local capacity for natural resource management in the wetlands.

In more specific terms, the objectives are:

- to summarise the benefits and values of the PTRCW, incorporating the results of the rapid inventory studies undertaken during 2013
- to provide tools to identify and reduce threats to these values by establishing a set of management guidelines that can be promoted to landholders, government agencies and natural resource managers, and
- to guide the use of the wetlands by identifying priority locations and activities for on-ground investment, to support and enhance the identified values.

In detail, the intended users and beneficiaries of these guidelines are: landholders of the PTRCW; other landholders in the catchment and wider Fitzroy Basin; NRM practitioners in Queensland, State Government agencies responsible for grazing land management, wetlands, water and NRM generally; and industry that may have present or future interests in the PTRCW catchment.

1.4 Scope of this document

Firstly, the management guidelines must be understood as being suggestions for landholders and others to consider, not prescriptions or regulations. On-site management decisions and action are ultimately at the (private) landholder's discretion, with the exception of Lake Murphy Conservation Park where decisions rest with the State Government. The Guidelines provide ideas to help land managers tailor their business decisions to current and future challenges facing them in the wetlands. Many graziers are actively applying principles for ecologically sustainable grazing in the PTRCW but it is recognised that there has been very little long-term research into grazing management systems and the impact of these systems on wetlands. This limits the scope of information and detail of guidelines that can be provided.

In principle the guidelines address the entire PTRCW site, which includes substantial areas of dry land (non-wetland), but in practice the primary focus is on the site's wetlands and their associated benefits and values.

After briefly summarising the ecosystem services and biodiversity values of the PTRCW, the document identifies threats to the services and values. The main body of the guidelines follows, with suggested responses (actions) linked to the relevant services, values and threats, described in detail.

Reports of the six investigations into PTRCW during 2013 have provided baseline information for development of the management guidelines. Some of the key findings relevant to the guidelines are summarised in sections below on Values and Threats, whereas full details are available in standalone reports published by FBA (Alluvium Consulting 2014a,b,c; Briggs 2014; FaunaTrack 2014; Halford & Fensham 2014).

Whereas the basis for material in these guidelines is largely scientific, supplemented by information from interviews and meetings, the presentation is deliberately more narrative than technical in order to optimise readability and uptake.

2 Values

2.1 Ecosystem services

The benefits or values that a natural site provides to human communities are known as 'ecosystem services' and this concept has been widely applied at global and national levels (DEWHA 2009). In seeking to identify ecosystem services and manage them for future generations, it is helpful to also recognise the 'ecological components' and 'ecological processes' that underpin the services, making them possible. The term 'ecological character' is sometimes used to refer to the assemblage of interrelated components, processes and services of a wetland (DEWHA 2008) and is useful for determining limits of acceptable change to a wetland.

Examples of ecological components in the PTRCW are:

- underlying geology and soils
- fresh water of specific conductivity, pH and turbidity
- submerged, floating and emergent aquatic vegetation
- tree, shrub and/or grass communities in the margins of, or buffering the wetlands
- invertebrates, fishes, waterbirds and other animals occurring in the wetlands.

Examples of ecological processes in the PTRCW are:

- rainfall and evaporation, specific to this area
- stream and overland flows of water into and out of the wetlands
- natural sedimentation in the beds of the channels and off-river wetlands
- seasonal growth and decay of annual wetland plants
- seasonal breeding by wetland-dependent animals.
- nutrient cycling in the water bodies

Comprehensive and sophisticated ecological character descriptions have been prepared for some of Australia's important wetland sites, but this requires a major research, analysis and consultation effort and has not been attempted for the present guidelines for PTRCW. However, drawing from published lists (e.g. DEWHA 2009, p. 8) it is possible to readily identify the primary ecosystem services provided by PTRCW:

A. Provision of **fodder** for farm livestock:
    - Whereas much of the fodder required to sustain cattle is gleaned outside of wetlands, under seasonal conditions the drying beds of swamps and lakes in the PTRCW commonly provide important sources of fodder, e.g. water couch.
    - This service may be especially important during dry spells or drought, when upland pasture is sparse or poor but drying wetlands still provide good fodder.
B. Provision of **water** for farm livestock:

- Livestock such as cattle require large quantities of drinking water and from the commencement of grazing enterprises, the PTRCW's numerous lakes and waterholes provided abundant natural sources.
- This service limited the investment that landholders needed to make in infrastructure for storage and delivery of water to livestock.
- Over the decades, sinking of bores and construction of farm tanks and dams has diversified the water sources, which has perhaps been most helpful in the Robinson Creek component given its generally shallower water bodies and flat landscape.
- Livestock still use many of the system's natural wetlands for drinking – especially in the Palm Tree Creek sector where steeper topography may allow some greater wetland depths and thus longer persistence of water.

C. **Recreation** sites for local people:
- Families of local landholders and some from farther afield have used some of the PTRCW waterholes and lakes for picnicking, swimming, fishing, boating and other compatible forms of recreation.
- Public access to the PTRCW is limited but camping and passive recreation such as nature appreciation can be undertaken at small scale by the public at Lake Murphy Conservation Park.

D. **Retention** of floodwater:
- As the 155 off-river wetlands of PTRCW fill mainly from the two main creeks as well as minor local creeks directly entering the swamps/lakes, the PTRCW thereby provides a service of floodwater retention whenever a moderate to major flood event occurs. The wetland plant assemblages also help to filter sediments and nutrients before they enter the main river system downstream.
- The greatest benefit to downriver towns and landholders would occur when the PTRCW are dry or relatively low in depth and are thus able to retain much of the floodwater from a major flood event. The service may be less significant when the wetlands are already full.

E. Indigenous and other **heritage**
- Indigenous heritage is associated with the PTRCW, because of the abundance of food and other natural resources that such places previously provided to indigenous residents of this country.
- Specific information on indigenous heritage has not been made available for compiling the present guidelines.
- European settlement heritage is also connected to the water and other natural resources that the PTRCW site continues to provide to local people.

Further information on ecosystem services is available in the Aquatic Ecology report (Alluvium Consulting 2014a: section 3.7).

2.2 Biodiversity values

Values may also be ascribed to the PTRCW in terms that do not refer to obvious benefits to humans, but to local, regional or global biodiversity. Reference to the six recent investigations and additional sources reveals the following biodiversity (intrinsic natural) values of the PTRCW:

1. A regionally-unique, densely clustered suite of **abundant wetlands**:
    - The PTRCW is a large area of natural wetland habitat comprising more than 155 component wetlands and, as well as the extensive habitat provided to plants and animals, this size and abundance confers intrinsic natural value.
    - Wetland complexes like the PTRCW and at its scale are rare in the Fitzroy Basin and the wider Brigalow Belt bioregion.
2. **Refugia** for rich & abundant communities of wetland dependent animals:
    - A rich assemblage of native wetland animals has been documented in the PTRCW: 55 species of waterbirds, 14 amphibians, eight fishes and two turtles; also 122 non-wetland bird species and 33 mammals (Kelly 2011; Briggs 2014; Alluvium Consulting 2014a; FaunaTrack 2014).
    - When surrounding or far-away regions are in drought, the PTRCW may provide vital refuge for many of these wetland species.
    - One group, waterbirds (Fig. 4), has been partly quantified and surveys in June 2013 tallied close to 10,000 individuals across 15 of the PTRCW lakes and swamps (Briggs 2014). Whereas a statistically robust sample would need to be surveyed to extrapolate meaningfully to the entire site, nevertheless preliminary indications suggest that over 20,000 waterbirds may sometimes use the PTRCW (Briggs 2014); this meets one of the criteria for international importance and thus potential designation of a wetland as a Ramsar site (DoE 2014b). Large numbers of waterbirds may be due to prolific local and regional breeding during a series of wet years and/or persistence of sufficient water in the PTRCW to offer drought refuge.
    - A notable example of the waterbirds is the uncommon Cotton Pygmy-goose *Nettapus coromandelianus*, with 61 birds recently recorded across 7 of the 15 surveyed wetlands (Briggs 2014).
    - Native fishes also can survive dry or drought periods in the PTRCW (Alluvium Consulting 2014a) although little water may remain in the swamps and lakes under severe or prolonged drought conditions as most are relatively shallow. Highest fish abundance in recent surveys was found in sites with greatest abundance of aquatic plants and woody debris (Alluvium Consulting 2014a).

Figure 4: Waterbirds, including swans, ducks, ibises and stilts, feeding in the grassy margins of a small wetland on the floodplain of Palm Tree Creek.

Photo by R. Jaensch

3. **Breeding habitat** for waterbirds and fish:
   - Whereas waterbirds need suitable feeding habitat, usually this can be found widely over wetland landscapes. Also, many species are versatile in the types of food they can exploit. Habitat for breeding is generally not available widely because many species require particular vegetation, often with specific water depth, for nest sites; waterbirds such as cormorants, herons and ibises normally breed in dense colonies, at very few sites. Thus, provision of breeding habitat for waterbirds is an especially important biodiversity value and this relates to a vulnerable/critical stage of the life cycle of these wetland-dependent animals.
   - Before 2013, few surveys of birds had been conducted in the PTRCW as the majority of the site has no public access, but surveys and other observations in 2013 (Briggs 2014; Alluvium Consulting 2014a; FaunaTrack 2014) provided the first systematic broad-scale assessment. Breeding was documented at 15 swamps/lakes and for 10 species of waterbirds and, though not quantified, this points to PTRCW playing a key role as breeding habitat. The number of waterbird pairs breeding is much higher in years of dry conditions to the north and west; this occurs once in about every 15 years (A. Clark pers. com.). Over 70 pairs of Black Swan breed on Nunbank Lake when it is full (A. Clark pers. com.).
   - The channels/waterholes, lakes and swamps of PTRCW provide interconnected habitat for freshwater fish; most of the recently surveyed wetlands supported juveniles, intermediate and adult fish, indicative of significant breeding habitat (Alluvium Consulting 2014a). It is likely that further research will show the PTRCW to be particularly important

as nursery habitat for a suite of native fishes. Fish support populations of waterbirds in the wetlands (Fig. 5), some in abundance.

Figure 5: Pelicans are among the fish-eating waterbirds supported by the PTRCW.

Photo by A. Briggs

4. A suite of **diverse plant communities** occurring in the wetlands, with high abundance:
   - A total of 190 plant species, including 35 aquatic plants, was documented in the wetlands by Halford & Fensham (2014); 44 of these were widespread non-native species but none were declared weeds in Queensland, and weediness was relatively low for this long-altered landscape (Alluvium Consulting 2014a).
   - Many of the site's wetlands are classified as one regional ecosystem (11.3.27) but documented sub-types and investigations by Halford & Fensham (2014) show considerable diversity within this class. Key factors in distinguishing sub-types include: composition and dominance of wetland plant species; shape, topography and diversity of landforms of the wetland; and soil chemistry.
   - The large number and geographical extent of wetlands in the PTRCW site also contribute to the diversity of plant communities in this one aggregation.
   - Although there is no detailed historical baseline for comparison, it may be argued that present and recent land-use practices have not greatly diminished (and possibly have in some respects contributed to sustaining) this diversity.
   - The diversity and abundance of aquatic habitats (plants, woody debris, micro-relief) provided by the PTRCW can potentially support aquatic macroinvertebrate communities (prawns, shrimps, yabbies) that are slightly more species-rich than wetlands elsewhere in the upper Dawson catchment (Alluvium Consulting 2014a).

Baseline surveys are still required for many aspects of the site's biodiversity, as mentioned in the project's survey reports. For example, in Australia's highly variable climate an adequate understanding of natural systems requires investigation over multiple years and different conditions. Consequently, additional biodiversity values are likely to be identified in the future.

2.3 National-level importance

The Directory of Important Wetlands in Australia was established during the 1990s (DoE 2014a) to collate inventory data on wetlands and identify priority sites for future conservation and management investment. Sites were included in the Directory – now accessible online through the Australian Wetlands Database (DoE 2014a) – if they met at least one of its selection criteria. As many of the criteria relate closely to criteria of the Ramsar Convention on Wetlands (DoE 2014b), potentially some of the DIWA wetlands may also be candidates for listing as a Wetland of International Importance (a 'Ramsar site').

The Queensland Government had earlier conducted inventory of wetlands using a methodology (Blackman *et al*. 1999) that allowed aggregations of wetlands to be defined as 'sites'. Through this process, the PTRCW site was defined and documented and it was included in DIWA on account of meeting two criteria. These criteria are re-examined as follows:

C1: It is a good example of a wetland type occurring within a biogeographic region in Australia.

- Brigalow Belt South is the applicable bioregion and the broad wetland types listed for the site in DIWA are: B10, seasonal freshwater ponds and sedge marshes; and B2, seasonal streams (DoE 2014a; Blackman et al. 1999).
- PTRCW has a large number and substantial area of wetlands of these types and as shown by recent field investigations, they are in relatively good condition (e.g. Alluvium Consulting 2014b).
- There are few if any other places like PTRCW. Arguably, Palm Tree and Robinson Creek Wetlands is a unique aggregation, not only in this region but also at broader scale, in terms of its dense cluster of abundant stream-fed waterbodies lying in the upper catchment of a river basin. Within the lower Fitzroy Basin, a large cluster of wetlands occurs on floodplain around Rockhampton ('Fitzroy River Floodplain': DoE 2014a) but the geomorphology, origins and types of wetlands there are substantially different to PTRCW.
- Accordingly, the continued meeting of C1 by this site is readily justified.

C5: The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.

- No evidence was presented in DIWA as to which taxa or communities were applicable, at the national level.
- The relevant population of a non-wetland species present at the site, Squatter Pigeon *Geophaps scripta scripta*, is presently listed as a threatened species (Vulnerable) in the national list maintained for the Environment Protection and Biodiversity Conservation

(EPBC) Act 1999. However, this species is not a wetland-dependent species and the main area of concern for this species is well to the south (DoE 2014c)
- Koalas *Phascolarctos cinereus* occur in the site; they were recorded at two sites in close association with Palm Tree Creek and/or extensive eucalypt woodland (FaunaTrack 2014). Koala is listed as Vulnerable under the EPBC Act but although occurring in eucalypts associated with watercourses, it is not wetland-dependent.
- It seems there is insufficient justification that this criterion is presently met by PTRCW.

A fresh review of the DIWA criteria shows that two additional criteria deserve consideration:

C3: It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.

- The 155 waterbodies of the PTRCW retain floodwaters in the upper catchment of the Dawson River (Alluvium Consulting 2014b).
- Floods sometimes occur downstream in the Dawson catchment, e.g. 2010, 2011.
- Thus it may be argued that the PTRCW site plays an important hydrological role in the Dawson River catchment and thereby meets C3.

C4: 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.

- The recent field investigations indicate that PTRCW provides substantial habitat for breeding by several waterbird species and drought refuge by many thousands of waterbirds (Briggs 2014; A. Clark pers. com.).
- The site also supports several native freshwater fishes (Fig. 6) and the off-river wetlands act as nursery areas for some species (Alluvium Consulting 2014a).
- Although some of these phenomena have not been fully quantified, due to the size of the site and number of wetlands there seems little doubt that the scale is large.
- Thus, it may be argued that the PTRCW site is important for waterbirds and fishes at a vulnerable stage and/or for drought refuge, and thereby meets C4.

In conclusion, the PTRCW are of national – and potentially international – importance, meeting between one and three of the criteria that refer to representativeness, hydrological role and animal life cycles.

Figure 6: Spangled perch, a native fish occurring in the PTRCW site.

Photo by frc environmental

3 Threats

Human enterprises and activities in natural landscapes tend to result in pressures that in some cases may become threats to the viability of ecosystem services and biodiversity values. Principal threats in the case of the PTRCW have been identified as follows:

1. Potential future **changes to river regimes**, causing reduction in volume, timing and/or frequency of flooding of the two major creeks and thereby depriving the site's wetlands of their major water supply:
   - This refers to river regulation caused by major upstream or on-site dams, weirs, irrigation offtake, and/or harvest of overland flow.
   - This threat may also influence other threats, e.g. invasive plants.
2. **Barriers to connectivity** between the major creeks and off-river wetlands, as well as changes to **retention of water** in lakes/swamps, either human-made or natural:
   - Examples of barriers include roads, banks or flood debris that close or restrict channel flow from creek to swamp, thereby reducing swamp water depth and area.
   - Water levels can also be affected by constructed or naturally-formed drains that lower water levels in the swamp/lake.
   - Barriers also include downriver dams and weirs that impede migratory movements of fishes and other aquatic species, some of which spend part of their life cycle in the sea (Alluvium Consulting 2014a).
3. Continued or increased **sedimentation** of streams and off-river wetlands resulting from erosion of degraded catchments:
   - Local soils in the Dawson catchment are naturally highly erosive (Alluvium Consulting 2014a).
   - Sedimentation will impact the channel waterholes, where changes can be most readily observed and measured, but also the off-river wetlands.
   - Extreme sedimentation will reduce the wetlands' ecosystem services of retention of floodwaters and recreational amenity, and alter some biodiversity values.
4. **Accelerated drawdown** of water levels in lakes/swamps due to changes to the groundwater system, possibly resulting from future mining or gas extraction or large scale irrigation:
   - While not an issue at present in the PTRCW, should extractive activities occur in the vicinity in the near future, it is possible that such impacts may occur.
   - Large-scale irrigation schemes using local bores, if ever widely established in the PTRCW, may also draw down water levels in nearby wetlands.
5. Long-term **loss of or change to wetland vegetation** including submerged, emergent and fringing communities, caused by **unsustainable grazing pressure** from livestock:
   - Communities of native plants persist in the wetlands but overgrazing and untimely access by cattle to these areas can lead to long-term change and loss.
   - Disturbance (pugging) of wetland soils and trampling by livestock can reduce water quality in swamps/lakes and increase erosion in creek zones.

6. Long-term **loss of or change to wetland vegetation** including submerged, emergent and fringing communities, caused by **invasive plants and/or feral animals** such as pigs (Fig. 7):
   - Invasive exotic plants and animals are a threat throughout the bioregion, removing or replacing native plant communities and altering habitats.
   - Frequent surveillance and regular coordinated remedial action are required.
7. **Insufficient awareness** by the public and land/NRM managers of the values and services provided by the site:
   - Whereas many landholders have intimate knowledge of the ecosystem services and biodiversity values of wetlands on their properties, naturally that is not universal and most outsiders are unaware of these assets.
   - This situation is an obstacle to generating the necessary management responses to protect and sustain the site's services and values.

Changes to climate may cause a range of changes to the PTRCW, including changes to vegetation, more pronounced flood and drought events and greater erosion and sedimentation. Climate change is thus a general, cross-cutting threat relevant to many of the above-listed specific threats. Adaptations to agricultural land use, particularly to management of soils, vegetation and water, will require coordinated efforts at catchment scale in order to address climate change.

Table 1 gives a preliminary overview of how the abovementioned threats apply to specific ecosystem services and biodiversity values of the PTRCW, and of the severity of these threats in the PTRCW.

Table 1: A preliminary overview of threats to ecosystem services & biodiversity values of the PTRCW

threat	ecosystem services					biodiversity values				severity
	A	B	C	D	E	1	2	3	4	
1 loss of water supply	X	X	X			x	X	X	X	H F
2 connectivity barriers	X	X	x	X		x	X	X	X	M L
3 sedimentation	x	X	X	X	x	x	X	X	X	H U
4 water drawdown	X	X	X			x	X	X	X	L F
5 overgrazing	X	x	x				X	X	X	M L
6 weeds & pest animals	X	x	X				X	X	X	M U
7 lack of awareness	x	x	x	x	x	x	x	x	x	M U

Notes: Ecosystem services are listed in section 2.1, biodiversity values in 2.2, above. Large 'X' and small 'x' serve to indicate magnitude of impact. Categories of severity; scale: H, M, S = high, medium, small; urgency to be addressed: U = urgent/now, L = less urgent, F = potential future threat. Entries are largely the opinion of the author and would benefit from extensive landholder consultation.

Review of Table 1 shows that some threats are severe but not yet realised whereas others are severe and ongoing. The most severe threats are judged to be loss of water supply and ongoing sedimentation. Sedimentation, weeds/pests and lack of awareness are considered to be the most urgent to be addressed. In terms of magnitude of impact, threats 1 to 4 and 6 seem the most serious (each greatly impacting 5 or more services or values) and ecosystem service A and biodiversity values 2 to 4 are the most threatened (each impacted greatly by 5 or more threats).

Figure 7: Damage to *Eleocharis* swamps caused by pigs.

Photo by R. Jaensch

4 Guidelines for management of the wetlands

4.1 Approach taken

The approach taken in preparing guidelines for management of the PTRCW has been to focus on the ecosystem services and biodiversity values of the site, in order to protect and sustain these assets. Accordingly, farm production and community interests have been broadly included.

Following some remarks to provide context or explanation, suggested responses to the major threats to these assets are outlined. These are based on collective knowledge of natural resource management in the region, recommendations from the six PTRCW technical reports and the experience of the author. The suggested responses have been grouped under four headings: water supply; livelihoods; biodiversity; and knowledge. It is acknowledged that some issues and responses apply to more than one category.

An indication is given in square brackets [ ] as to who might potentially be involved in implementing or otherwise contributing to (e.g. funding) each response. ('Landholders' principally refers to graziers.) Inclusion of particular stakeholders or parties is open to discussion and order in these lists is not by priority or scale of commitment.

FBA welcomes feedback from landholders and others who through implementing these responses may identify new methods or useful adaptations that would improve outcomes.

4.2 Water Supply

4.2.1 Maintain Palm Tree Creek and Robinson Creek as free-flowing streams

In support of: Ecosystem Services A, B and C and Biodiversity Values 1, 2, 3 and 4.

Addressing: Threat 1 (loss of water supply)

Remarks:

The most devastating potential impact on the PTRCW would be a major reduction in water supply via Palm Tree Creek or Robinson Creek, because these streams are the greatest suppliers of water to the off-river wetlands (Alluvium Consulting 2014b). Figure 8 illustrates an almost-dry wetland landscape.

The degradation or total loss of downstream wetlands following river damming, regulation and/or introduction of major irrigation schemes has been well documented, worldwide (International Rivers 2014). Loss or severe reduction of natural river flows, especially the moderate to major floods, would greatly alter the natural functioning of the PTRCW wetlands and their biodiversity and would affect floodplain grazing enterprises. The impact of land use practices (in this case, pastoral grazing) becomes more significant where wetlands are stressed, such as due to reduced flooding, and stressed wetlands are more

Figure 8: Lake Murphy, almost dry: likely to occur more often if water supply is denied.

Photo by R. Jaensch

vulnerable to long-term damage from short-term grazing decisions. Removal of flooding can reduce the extent of the soil seed bank and the plant community then may contain many short-lived annual species in both grazed and un-grazed sites (Holmes et al. 2009). Changes to frequency and depth of inundation may affect infestations by lippia, an invasive weed (see section 4.4.1).

At present there are no substantial dams or weir structures within the catchments of Palm Tree Creek or Robinson Creek, nor widespread and substantial pumping of water from the creeks for irrigation or other uses. However, new proposals for water storage or harvest may arise in the future if agriculture or mining and gas extraction industries undergo changes that create new demands for water supply.

Suggested responses:

a. Lobby the State and regional agencies responsible for water to ensure that protection of all flows in Palm Tree Creek and in Robinson Creek is adopted as a principle and is stated clearly in strategic planning documents [Action by: landholders, FBA, DCCA, WPSQ and other natural history groups, major extractive industries, State Government].
b. Maintain vigilance to ensure that stakeholders are adequately informed, well in advance, regarding any development proposals relevant to water supply [Action by: All, as in (a)].

4.2.2 Remove barriers to connectivity between supply creeks and swamps/lakes and ensure that no increased drainage of wetlands occurs

In support of: Ecosystem Services A, B, C and D and Biodiversity Values 1, 2, 3 and 4.

Addressing: Threat 2 (connectivity barriers)

Remarks:

Many of the PTRCW off-river swamps and lakes receive the greatest contribution to their water supply from Palm Tree Creek or Robinson Creek (Alluvium Consulting 2014b). At times this occurs from floodplain-wide inundation; during lesser floods, this is via connecting channels. Such channels may be many metres wide and several metres deep (Fig. 9), or relatively small but nonetheless vital conduits of water.

Figure 9: A connection channel between Robinson Creek and a floodplain lake.

Photo by R. Jaensch

These channels can become blocked by accumulation of sediment and/or log debris, especially after a major flood event. Even quite small obstacles could deny a large volume of inflow to a swamp. Also, human-built structures to improve creek crossings or low-lying sections of road, or to redirect floodwaters away from infrastructure, could become obstacles to wetland inflow. Changes to the frequency and depth of inundation of wetlands have multiple implications for ecosystem services and biodiversity values, e.g. changes to infestation by invasive weeds (see section 4.4.1).

Whereas natural blockages of channels may be relatively small in scale and localised, clearance of blockages may be time-consuming for landholders to undertake. In the case of crossings and road-works, appropriate design before construction will alleviate the need for costly remediation at a later stage.

Similar impacts to local denial of water supply can result from natural or human-made interventions that reduce the holding capacity of the swamps and lakes. Examples include breaching of natural levee banks due to land use practices, and intentional drainage of wetlands. Extreme natural flood events may also cause erosion that drains a wetland.

Connectivity issues also exist outside the PTRCW site. Observed declines in numbers of large eels in the PTRCW over several decades shows that downriver dams and weirs are inhibiting migration of fishes (Alluvium Consulting 2014a, c).

Suggested responses:

a. Design of new or repaired creek crossings for Shire and private roads should ensure optimal flow past the crossing or embankment by inclusion of culverts or pipes of sufficient capacity [Action by: Shire council, landholders].
b. Farm activities that break natural ponding levees or deliberately drain swamps/ lakes should be avoided [Action by: landholders].
c. Existing NRM grant schemes could be expanded in scope, or a new small grant scheme could be established, to provide funds to landholders to clear major naturally-formed obstacles to connecting flows, modify crossings, repair natural levee banks, or close drains [Action by: FBA, DCCA, major extractive industries].
d. Fish passage facilities could be installed on existing barriers (downstream weirs), and construction of new in-stream structures downstream between the PTRCW and the sea should be avoided [Action by: State Government, Shire council, FBA, DCCA, major extractive industries].

4.2.3 Minimise sedimentation in the wetlands

In support of: Ecosystem Services A, B, C, D and E and Biodiversity Values 1, 2, 3 and 4.

Addressing: Threat 3 (sedimentation)

Remarks:

Whereas sedimentation is a natural process, it accelerates greatly once tree cover has been removed or reduced as part of the establishment of agriculture in a catchment. In the upper Dawson catchment, erosion of exposed soil during heavy rain events has led to transport of sand and silt downstream, with deposition occurring in still or slower-moving water bodies such as waterholes (Fig. 10), lakes and swamps. The Fitzroy Basin is one of the major contributors of sediment to the lagoon of the Great Barrier Reef (SoQ 2013).

Figure 10: Accumulated sediment in the bed of Robinson Creek.

Photo by R. Jaensch

Whereas some of the most serious sedimentation must have occurred in the early years after tree clearing, major increases in channel-bed and lake-bed deposits can recur with intense rain events in the catchment – especially if summer grass cover has not yet regrown or become well established. Sedimentation is also an ongoing issue if grazing of domestic livestock and cropping practices are inappropriate.

It is, however, acknowledged that the wetlands are dynamic, gradually changing over tens or hundreds of years. Sudden large-scale change can occur after huge floods when, for example, new erosion channels may form and drain a lake (A. Clark pers.com.). Impacts of sedimentation thus need to be considered in this context.

The impacts of sedimentation on ecosystem services and biodiversity values of wetlands are many. Shallowing of water basins and channels may reduce their water holding capacity and shorten the period before they dry out. Change from deeper to shallower wetlands throughout a catchment will impact farming (e.g. reduced water supply), the wider community (e.g. recreation sites not available in driest months), and natural wetland processes, e.g. insufficient inundation period to enable completion of waterbird breeding. Some interviewed PTRCW landholders expressed concerns that, as a result of sedimentation, a number of wetlands have become shallower and wider, leading to flooding of the wetlands over wider areas (Alluvium Consulting 2014a, c). Lake Murphy is considered to have expanded in area and Robinson Creek is slowly silting up the outlets/connections to its off-river swamps and lakes (A. Clark & others, in Alluvium Consulting 2014c). Changes to the shape and size of wetlands linked to sedimentation may be impacting the stability of natural levees that keep water in the PTRCW swamps and lakes (Alluvium Consulting 2014b). Also, filling of a lake with sediment may lead to overspilling that can create a new erosion channel that subsequently drains that wetland (A. Clark pers. com.).

Suggested responses:

a. Promote and participate in catchment-wide initiatives to reduce soil erosion [Action by: FBA, DCCA, landholders, major extractive industries].
b. Extend or take up best practice in regard to grazing regimes at the property level: see section 4.3.1 below [Action by: landholders].
c. Avoid further clearing of regrowth vegetation or, where that is approved, conduct clearing in a way that minimises soil erosion; clearing along drainage and creek lines and on highly erodible slopes and soils should be totally avoided [Action by: landholders, major extractive industries, Government regulators].
d. Consider the methods, costs and benefits of de-silting some relatively small but high-profile waterholes/wetlands that could serve as test cases for potential wider implementation [Action by: FBA, DCCA, landholders, major extractive industries].
e. Further and more comprehensive studies of the geomorphology, hydrology and sources of erosion and sediment transport of the PTRCW are needed, to better inform management planning [Action by: Federal & State Governments, FBA, DCCA, major extractive industries].

4.2.4 Prevent the possible contribution of mining and gas extraction to drawdown in wetlands

In support of: Ecosystem Services A, B and C and Biodiversity Values 1, 2, 3 and 4.

Addressing: Threat 4 (water drawdown)

Remarks:

As the PTRCW site is within Queensland's actively developing Surat/Bowen coal and gas basins, impacts of major extractive industries on the groundwater and water quality of the PTRCW could possibly occur in the near future. If mining or gas extraction causes lowered water tables, this possibly could result in water levels in some of the PTRCW wetlands also becoming lower, reducing their ecosystem services and biodiversity values due to earlier drying-out. And pollution due to release of contaminated surface water from mine dewatering or from flooded mines could render connected wetlands unsuitable for water supply and for aquatic life. Some of these impacts may not be obvious in the short-term.

Presently, there is no active mining or gas extraction in the PTRCW site. Furthermore, the preliminary hydrological investigations (Alluvium Consulting 2014b) did not identify a definite or substantial interaction between groundwater and water levels in the PTRCW wetlands. Hence, this is an unconfirmed but potential issue. Nevertheless, as it is of considerable concern to many PTRCW landholders, further hydrological investigation into groundwater interactions should be conducted.

Suggested responses:

a. Further research on the possible impacts of mining/gas extraction on surface wetlands of the PTRCW and elsewhere should be conducted by resource development companies and verified by independent experts [Action by: major extractive industries, Government regulators].
b. Approval for any new mines/extraction in the catchment or surrounding region of the PTRCW should be dependent on the proponents providing clear management and monitoring plans to protect local and regional water values to ensure that local and regional water tables and water quality will not be compromised [Action by: Government regulators, major extractive industries].

4.3 Livelihoods

4.3.1 Implement appropriate grazing regimes for wetlands

In support of: Ecosystem Services A, B and C and Biodiversity Values 2, 3 and 4.

Addressing: Threat 5 (overgrazing)

Remarks:

Activity of cattle in water bodies has many impacts. Pugging of the soil disturbs bottom sediments which increases water turbidity; also, pugging can destabilise channel banks. Cattle activity increases coliform bacteria and nutrient levels in the water. Cattle browse many species of wetland plant, both emergent and submerged: this reduces the extent of some wetland plant species and promotes growth of other species. If wetland plants are browsed too early, they may not flower and/or set seed to ensure viability through coming years. Some nesting waterbirds may lose their nests due to cattle browsing and trampling.

There is no adequate baseline of what aquatic and other wetland plant communities occurred in the PTRCW wetlands before cattle grazing began. However, studies on inland floodplain wetlands in Australia confirm that grazing can alter the composition of plant communities and that overgrazing can result in wetland degradation that cannot always be reversed (Holmes *et al*. 2009). Some leafy, tall wetland plants such as common reed *Phragmites australis* decline or have been lost under cattle grazing regimes (Holmes *et al*. 2009). Some waterbirds prefer to inhabit or nest in specific wetland plant communities that may be reduced or lost in heavily- grazed situations, e.g. Comb-crested Jacanas *Irediparra gallinacea* nest on the floating pads of water lilies *Nymphaea* spp. (Fig. 11). Nevertheless, communities of native plants and animals persist in the PTRCW wetlands and co-exist with the cattle of grazing enterprises, probably having done so over many decades. In part this may be so because cattle naturally spend less time in wetlands when water levels are high and dry-land areas are green, than when water and feed are scarce. Successful co-existence may also reflect sound management of cattle grazing.

Figure 11: Comb-crested Jacanas prefer extensive areas of water lilies that may become scarce in overgrazed wetlands.

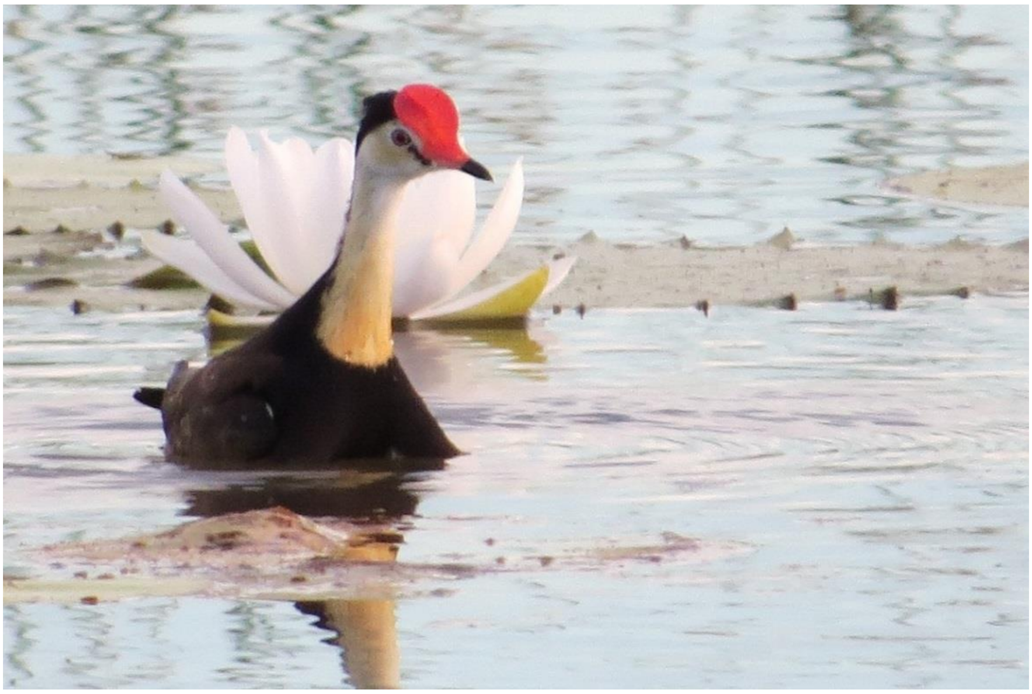

Photo by R. Jaensch

Choice of the best grazing regime for properties in the PTRCW may include consideration of set stocking, tactical grazing, rotational grazing, and/or time-controlled grazing. Rotational grazing with different 'trigger points' per paddock for moving stock on, has been commonly adopted in the Gwydir wetlands, NSW. But tactical grazing is also recommended for use in the wetlands due to its flexibility and potential positive economic and environmental outcomes (Holmes *et al*. 2009). Ultimately, the local grazier has best knowledge of what will work best locally.

Design of the detail for suitable grazing regimes for wetlands can start by following best management practice for grazing in the local landscapes, then adding facets specific to wetlands (see Holmes *et al.* 2009). For example:

- overgrazing is to be avoided because it can result in wetland degradation that cannot always be reversed
- some grazing may help to maintain diverse wetland plant communities
- a precautionary approach should be adopted when determining rates of stocking; rates should be based on the response of the most sensitive parts of the ecosystem
- the impact of total grazing pressure – stock plus feral and native herbivores – should be considered
- seed banks and rhizomes of wetland plants should be maintained and establishment of new growth and seed setting by wetland plants should be optimised.

Implementation of appropriate grazing regimes for wetland areas can retain and protect existing wetland plant communities, thereby improving environmental outcomes and economic benefits for graziers. This is because healthy wetland systems tend to hold more water, produce more plant biomass, support a wider range of habitats, and show greater resilience (Holmes *et al*. 2009).

Suggested responses:

a. To account for the variable climate, in wetland areas graziers should apply best management practice proven for this region, including: having annual and seasonal flexibility in grazing management practices; responding to changes in pasture and flooding by moving stock between paddocks or removing stock completely from parts of properties; using conservative stocking rates; and matching animal requirements to seasonal pasture availability [Action by: landholders].
b. Also, graziers should: identify pasture species and understand how they respond to grazing pressure; manage for total grazing pressure exerted by livestock and native/feral herbivores; and maintain appropriate levels of ground cover. A target of 70% groundcover (vegetation, leaf litter and plant debris) is recommended as the minimum groundcover to be maintained in all dry wetland communities (Holmes *et al.* 2009) [Action by: landholders].
c. To optimise a diverse community of native wetland plants, grazing of the wetland should be avoided at certain times: at the onset of flooding (after a flood or heavy rainfall); early in plant growth cycles when new shoots are developing; when native plants are flowering, seeding and establishing in degraded wetlands; during wetland drying where soils are still wet and prone to compaction and pugging; and when inundation frequency becomes low (Holmes *et al*. 2009) [Action by: landholders].
d. Practices specific to key wetland plant species have been recommended for inland northern NSW (Holmes *et al.* 2009) and may be worth testing in the PTRCW, e.g. always maintaining at least 50% of the bulk of water couch growth. Similarly, stocking rates for those wetlands could be trialled in the PTRCW (see Wilson *et al.* 2008; Holmes *et al.* 2009) [Action by: landholders, DCCA, FBA].
e. Consider other investigations and trials to enhance production and environmental outcomes in the PTRCW, including: establishing one or two semi-permanent grazing exclusion plots (excluding stock and native herbivores) to help compare the impacts of grazing with no grazing; and reducing the size of paddocks for more frequent resting of pastures following flooding as this will also help seed set (Holmes *et al.* 2009) [Action by: landholders, DCCA, FBA].

4.3.2 Fence to control access of livestock to wetlands

In support of: Ecosystem Services A, B and C and Biodiversity Values 2, 3 and 4.

Addressing: Threat 5 (overgrazing)

Remarks: As discussed in the previous guideline (4.3.1), control of access by cattle to wetlands is desirable as an integral part of a pastoral grazing regime. Greater use of fencing is a key strategy to achieve this. Use of fencing to restrict cattle access to water bodies has enhanced farm production and improved the quality of other wetlands – like those in the PTRCW – in the upper Dawson catchment (Alluvium Consulting 2014a; FBA 2006). Total exclusion of livestock usually would be undesirable because stock access wetlands (Fig. 12) for fodder and sometimes for drinking water (though some cattle seem to prefer the mineralised bore water available in off-wetland troughs: A. Clark pers. com.).

Figure 12: Cattle in one of the PTRCW wetlands.

Photo by J. Halford

Some considerations for the design of fencing and paddocks involving wetlands have been identified (Holmes *et al.* 2009). It is generally accepted that smaller paddocks grazed for shorter periods: allow greater pasture utilisation when compared to larger paddocks containing the same number of cattle; reduce selective grazing and overgrazing; but require more intensive management. Benefits of smaller paddocks include: increased production through better weight gains and higher stocking rates; increased ecological outcomes; and controlled management of seed set in wetlands. Graziers who have adopted the practice of smaller paddocks grazed for shorter periods have installed more off-wetland watering points (see section 4.3.3). It can be helpful to have both high and low ground within wetland paddocks.

In view of the large number of wetlands in the PTRCW system, it would be realistic to plan fencing to control stock access at selected high priority areas, such as creeks with high banks and swamps/lakes – or large portions thereof – that have especially high value for biodiversity. The recent surveys of Briggs (2014) and Halford & Fensham (2014), due to resource and access issues, could not cover all of the PTRCW system. Hence, additional survey work would be needed in order to systematically identify the highest priority areas across the entire PTRCW.

Suggested responses:

a. Landholders are encouraged to identify specific swamps and lakes that are particularly important for waterbird, fish and/or plant communities, and vulnerable sections of creek bank, and feature them in property plans as targets for partial or total fencing to control cattle access. If necessary, funding may be needed to conduct surveys that would complement landholder knowledge [Action by: landholders, DCCA, FBA, major extractive industries].
b. In order to then establish fencing around or in portions of the priority wetlands, landholders will benefit from existing co-funding schemes to assist with costs of fencing (e.g. see FBA 2014a) [Action by: landholders, DCCA, FBA, major extractive industries].
c. Due to the history of grazing and existence of weeds in the catchment, seasonal or occasional grazing of totally fenced-off wetlands may be desirable to control weeds [Action by: landholders].
d. Promotion of successful demonstration models of the above actions would guide and encourage landholders, e.g. the FBA (2006) brochure "On the ground: Fencing wetlands near Taroom" [Action by: FBA, DCCA, State Government].
e. On some properties or in some paddocks where natural and artificial water supply is scarce, the above actions may need to be undertaken in conjunction with provision of off-wetland water points (see below, 4.3.3).

4.3.3 Establish off-wetland watering points

In support of: Ecosystem Services A, B and C and Biodiversity Values 2, 3 and 4.

Addressing: Threat 5 (overgrazing)

Remarks:

This guideline should be read in conjunction with the guidelines on grazing regimes (see above, 4.3.1) and fencing to control stock access (4.3.2).

In those situations where total or seasonal exclusion of stock from certain wetland areas, especially waterholes, may seriously impact water supplies for livestock, it might be necessary to provide alternative points of water supply. This has been a successful deliberate strategy for managing the impacts of livestock grazing on pastures and on wetlands in Queensland (e.g. FBA 2014b). As has already been widely practised in the PTRCW area, off-wetland watering points can be supplied by piping from a bore or farm dam. Pumping directly from a waterhole or lake may be less appropriate due to immediate negative impacts on the wetland.

In establishing alternate watering points, graziers should where possible install trough systems rather than ground tanks or dams. This is because troughed water: usually provides higher water quality; results in greater animal weight gain; reduces overall soil disturbance; and can be emptied when not in use, thereby helping to decrease total grazing pressure (Holmes *et al*. 2009).

Suggested responses:

a. Existing schemes for co-funding support to landholders wishing to establish off-wetland watering points should be promoted and extended in the PTRCW area [Action by: FBA, DCCA, landholders, major extractive industries].
b. Promotion of successful demonstration models of off-wetland watering points would guide and encourage landholders [Action by: FBA, DCCA, State Government].
c. The above actions may be done in conjunction with installation of fencing to control stock access to wetlands (see 4.3.2).

4.4 Biodiversity

4.4.1 Control invasive plant and animal species

In support of: Ecosystem Services A, B and C and Biodiversity Values 2, 3 and 4.

Addressing: Threat 6 (weeds and pest animals)

Remarks:

Swamps and lakes that possess a high diversity of native vegetation, including woody plants and emergent, floating and submerged plants (perennial and/or annual) tend also be rich in species of wetland animals because of the many habitat options available. However, invasive plant species can choke out wetland vegetation, even to the extent that natural communities of plants and animals are excluded, and can reduce or exclude valuable pasture for livestock grazing.

Lippia (Condamine couch) *Phyla canescens* (Fig. 13) has been present in the PTRCW for several decades and was recorded at 24 of 52 recently surveyed PTRCW wetlands (Alluvium Consulting 2014a; Halford & Fensham 2014). Flourishing in clay soils of floodplains, it prefers areas that receive intermittent or shallow inundation and has an aversion to prolonged inundation. It forms dense extensive mats (Fig. 14) with deep tap roots and thus is drought resistant and exacerbates riverbank erosion by contributing to deep soil drying. Lippia expands rapidly once established, disperses with floodwaters and shows limited response to chemical treatment.

Figure 13: Detail of lippia *Phyla canescens*, a weed of floodplain wetlands.

Photo by R. Jaensch

Lippia is seldom grazed by livestock and under certain conditions it may out-compete native wetland species, such as water couch, that are desirable as cattle fodder. In extreme cases, lippia can cause total destocking, so it is a serious weed though it is not yet a declared plant in Queensland. Graziers in the Gwydir Wetlands, NSW, indicated that Dry Sheep Equivalent stocking rates where lippia occurs are up to half those reported for other semi-arid floodplains; reduced grazing productivity is widely reported (Robertson 1998; Wilson *et al.* 2008; Leigh & Watson 2004). In a 2003 assessment, lippia infested over 5 million ha of the Murray-Darling Basin at a cost to the grazing industry of $38 million per year. Lippia is not yet considered a major problem for agriculture or the environment in the PTRCW or the Fitzroy Basin generally, but in climatic terms the Dawson catchment is well within the parameters for lippia to flourish (Julien *et al*. 2004, Stokes *et al.* 2008, & MacDonald *et al.* 2012).

Some conditions that favour lippia can be avoided or minimised. In the Gwydir Wetlands and Macquarie Marshes of inland northern NSW, McCosker (1994) noted that: successful lippia establishment often occurred following prolonged, repeated or intense disturbance; that long-term changes to the water regime of wetlands together with overgrazing favoured the establishment and growth of lippia; and that bare soil and reduced vigour of existing native species contributed to the rapid expansion of lippia. Several of the widespread native wetland plants of the PTRCW, notably the spike-rushes *Eleocharis sphacelata* and *E. plana* and water couch, can outcompete lippia under favourable conditions, including lack of overgrazing (Mawhinney 2003, Price *et al.* 2010 and Macdonald *et al*. 2012). Lippia seems most successful at recruitment following winter or frequent floods of shorter duration, as would occur in a regulated river system – a scenario not prevailing in the PTRCW. Floods causing inundation longer than three months reduce lippia density due to seedling mortality (Stokes *et al.* 2008).

Figure 14: Carpet of lippia *Phyla canescens* at Lake Murphy, excluding other plant species.

Photo by R. Jaensch

The absence or scarcity of deep-water ('ponded pasture') grasses in the PTRCW (none recorded at 52 surveyed sites: Halford & Fensham 2014) is presently an asset of the PTRCW, distinguishing the system from many other wetlands in the Fitzroy Basin. Introduction of ponded pasture grasses such as Olive Hymenachne *Hymenachne amplexicaulis* (a Class 2 declared plant in Queensland) potentially could occur from source areas downriver of the PTRCW; such grasses create an elevated fire hazard and exclude oxygen from water bodies, which is detrimental to native fish populations. There are significant infestations of Cat's claw vine *Macfaydena unguis-cati* (a Class 3 declared plant in Queensland) along parts of Palm Tree Creek and these could spread to wetland vegetation around the PTRCW. Parkinsonia *Parkinsonia aculeata* (declared Class 2), which can form dense thickets that exclude livestock and native fauna, also could become a serious problem. Awareness raising and timely control actions are needed for all serious weeds.

Presence of feral pigs *Sus scrofa* was documented from almost all of the 52 wetland sites in the PTRCW recently surveyed by Halford & Fensham (2014). Pigs dig in wetland margins, altering vegetation communities, resuspending sediment, predating native frogs and birds and spreading disease. Methods for control of pigs are well documented (DAFF 2014).

Whereas invasive fishes are relatively few and in low abundance now in the PTRCW, mainly mosquito fish *Gambusia holbrooki* (Alluivium 2014a), potential for invasion by other ecologically disruptive species including tilapia must be kept in mind. Future creation of downriver impoundments that become stocked with non-native species (for anglers) may increase the threat of new invasive fishes.

Suggested responses:

a. Participate in neighbourhood, catchment and regional control programs on feral pigs and invasive plant species [Action by: landholders, DCCA, FBA, State Government, major extractive industries].
b. Maintain surveillance to detect occurrences of declared weed species and exotic fishes in the PTRCW and plan eradication [Action by: landholders, DCCA, FBA].
c. Control and reduce lippia infestations using a combination of strategies including maintenance (not reduction) of natural flooding regimes, optimising conditions for native wetland vegetation, and generally applying best management practice for pastoral grazing (see 4.3.1). Early intervention may avoid more costly and less effective later action [Action by: landholders, State Government].
d. Raise awareness of present and potential threats from invasive species to wetlands of the PTRCW through provision of information [Action by: FBA, DCCA].

4.4.2 Manage trees in and beside wetlands to optimise benefits for biodiversity

In support of: Biodiversity Values 2, 3 and 4.

This guideline does not directly relate to the main ecosystem services of the PTRCW but is significant in relation to the biodiversity values. It does not address one of the primary threats (section 3, Table 1) but targets the loss or lack of some secondary components of wildlife habitat.

Remarks:

Wetland habitats are most supportive of wildlife where a diversity of habitats is available. Trees are an important component of wetland habitats, either in shallow areas where their roots can dry out seasonally, or nearby on dry land. They offer nest sites for waterbirds (especially in old trees that have hollows) and refuge for other animals; they also provide shade over waters inhabited by fish and drop branches that create good fish habitat (Fig. 15). Whereas tree-less lakes and swamps can be highly attractive to and are preferred by many waterbirds, they may not provide nesting habitat or other shelter for some species and thus a wetland system will have greatest biodiversity value if including both open and timbered wetlands.

As suggested by vegetation mapping (DEHP 2014b), before European settlement most of the PTRCW wetlands were surrounded by trees and many were shallow enough to have trees growing throughout. During the development of farming, in many wetlands the trees were partly or totally cleared.

Figure 15: A wetland with a mix of trees of different ages and some fallen logs can provide diverse habitats for wetland animals.

Photo by R. Jaensch

Because wetlands are naturally dynamic systems, some trees are killed by drowning in especially wet periods (Fig. 16). Other influences include fire, disease and invasive plants such as cat's claw creeper (see 4.4.1 above).

This overall loss of trees could be offset by replanting at some, but not all, wetland sites. Meanwhile, revegetation may occur naturally where extensive regeneration from seedlings occurs after wet periods, such as in 2010-2011. It is acknowledged that some landholders may be concerned at short-term loss of pasture under these tree thickets but in time many seedlings will die and only some will grow to maturity. Advice from experts on vegetation management may be helpful.

Suggested responses:

a. Develop awareness material that explains the biodiversity values of trees in and beside streams, lakes and swamps and promotes a landholder approach to management of such trees (including seedlings), which will optimise both habitat diversity and farm productivity [Action by: FBA, State Government].
b. Prevent any permanent increase in depth and persistence of wetlands, such as by damming or otherwise altering the hydrology, which may kill seasonally inundated trees in the wetlands [Action by: landholders].
c. Avoid removal of dead trees, logs and snags from streams, lakes and swamps except where temporarily and seriously impeding normal stream flow [Action by: landholders, Shire council].

Figure 16: Dead trees in a dry PTRCW wetland, possibly killed by drowning and/or fire.

Photo by R. Jaensch

4.5 Knowledge

4.5.1 Promote the values and wise use of the site's wetlands by using suitable media and methods and expand the knowledge base

In support of: Ecosystem Services A, B, C, D and E and Biodiversity Values 1, 2, 3 and 4.

Addressing: Threat 7 (lack of awareness)

Remarks:

Most of the component wetlands of the PTRCW are relatively small and in their own right are not well 'known' outside the property, catchment, bioregion or State. This low profile undoubtedly restricts interest, especially by funders, in supporting management responses in the PTRCW, to sustain its ecosystem services and biodiversity values. To counter this knowledge deficit, these services and values might best be made known collectively, as a wetland system, and NRM managers and other advocates therefore should promote the PTRCW site accordingly.

Awareness-raising should target all levels of the community and can be achieved in diverse ways using the several methods and media available today.

Despite a recent surge in knowledge of the PTRCW, many gaps remain, which prevents optimal management of the site's assets. Some such gaps have been mentioned in the above guidelines and the six recommendations of Alluvium Consulting (2014a: see the Summary) give details. To these may be added the benefits of learning from indigenous knowledge of the PTRCW, which may contribute additional management options.

Suggested responses:

a. Produce printed materials that enable landholders and other stakeholders to readily and visibly demonstrate the services and values of the PTRCW [Action by: FBA, DCCA, State & Federal Governments, corporate sponsors].
b. Establish and maintain a suite of internet pages, perhaps hosted by FBA or DCCA and linked to other relevant sites (including EHP's *WetlandInfo* http://wetlandinfo.ehp.qld.gov.au/wetlands/), that provide comprehensive information about the PTRCW. Information can be tailored to avoid mention of property names or landholders, if requested [Action by: FBA, DCCA, State Government].
c. Include the PTRCW in regular wetland-related activities in the catchment and region, e.g. World Wetlands Day [Action by: State Government, FBA, DCCA, landholders].
d. Support further studies of the PTRCW, in seasonal and decadal timeframes, to fill gaps in knowledge such as an adequate understanding of wetland ecology and suitable responses to short-term and long-term climatic shifts [Action by: FBA, State Government, Federal Government, major extractive industries].
e. Investigate and, as appropriate, document indigenous knowledge of the PTRCW [Action by: DCCA, FBA].

4.6 Recommended priorities for action

Not all of the suggested management responses listed above in sections 4.2 to 4.5 will be feasible under prevailing circumstances, so it can be helpful to identify the highest priorities for action. In the present project, it was not possible to interview a large number of PTRCW landholders to obtain their opinions on this question. However, interim recommended priorities for action have been identified by the author using the analysis of data in Table 1, focusing on threats that are urgent as well as severe or greatly impacting the most ecosystem services and biodiversity values:

4.6.1 Recommended priority actions to address sedimentation

- Promote and participate in catchment-wide initiatives to reduce soil erosion [Action by: FBA, DCCA, landholders, major extractive industries].
- Extend or take up best practice in regard to grazing regimes at the property level [Action by: landholders].
- Avoid further clearing of regrowth vegetation or, where that is approved, conduct clearing in a way that minimises soil erosion; clearing along drainage and creek lines and on highly erodible slopes and soils should be avoided [Action by: landholders, major extractive industries, Government regulators].

4.6.2 Recommended priority actions to address weeds/ferals

- Participate in neighbourhood, catchment and regional control programs on invasive plant species and feral pigs (Fig. 17) [Action by: landholders, DCCA, FBA, State Government, major extractive industries].
- Maintain surveillance to detect occurrences of declared weed species and exotic fishes in the PTRCW and plan eradication [Action by: landholders, DCCA, FBA].
- Control and reduce lippia infestations by a combination of strategies including maintenance (not reduction) of natural flooding regimes, optimising conditions for native wetland vegetation, and generally applying best management practice for pastoral grazing (see 4.3.1) [Action by: landholders, State Government].

Figure 17: Feral pigs digging at a wetland edge.

Photo by J. Drimer

These priority actions are not radically new concepts: most are already being pursued to some extent in the PTRCW site, within the FBA region and farther afield. This at least shows that caring for wetlands can be readily integrated into general NRM actions across Queensland landscapes.

It should also be noted that these guidelines do not call for establishment of new conservation reserves; it seems very reasonable to expect that desired outcomes can mostly be achieved under existing land tenure and land use. Nevertheless, there may be a place for discussion among stakeholders on the best options for strengthening protection (e.g. Nature Refuge status, or a higher level) and active management of some of the site's component wetlands/clusters.

Although the threat 'lack of awareness' was marked in Table 1 as urgent, it was not scored as severe or as greatly impacting many services and values. The present FBA project is, however, addressing this matter through production of technical reports, these guidelines and other publications. Additional responses could include establishing website pages dedicated to the PTRCW and linking these to EHP's *WetlandInfo* website.

One of the constraints of the project from which these guidelines have been formed is that access by the technical survey teams to all properties was not possible. This partly reflects lack of sufficient time to connect and build relationships with landholders who were not already engaged in organised NRM activities. In the absence of a geographically comprehensive base of information, at present it is therefore inappropriate to identify priority locations and specific activities for on-ground investment at those locations. If there is sufficient landholder interest, FBA and DCCA could work over a sufficiently long time period to address this knowledge gap.

5 Monitoring & Review

Monitoring refers to the testing of specific hypotheses: collection of data without a clear purpose can be wasteful of effort. For the PTRCW, the basic hypothesis could be that implementation of the above guidelines is making a significant improvement to the ecosystem services and biodiversity values of the PTRCW. The hypothesis may need to be addressed in the context of landholder participation as a result of using the guidelines, because there are also other drivers for landholders to take such actions. It could be tested through a series of well-designed questionnaire surveys.

Preconditions for such monitoring will be uptake of the guidelines by a sufficient number of PTRCW landholders, an adequate program of measurement of services and values against established baselines, and a scientifically robust assessment to demonstrate that changes are both positive and statistically significant. These ideals may be difficult and costly to attain. Therefore, a realistic approach may be to focus on one or a few services/values, such as those related to the recommended actions of highest priority (see section 4.6 above).

A future review of the guidelines should be conducted to assess their ongoing relevance and to update them to take account of new information and technologies. If a substantial body of new information is obtained or new management techniques are defined, relevant to the guidelines, such review ought to be conducted within 2-3 years following arrival of the new data/techniques. If no new data are collected on the PTRCW, such review should be conducted in 5-7 years' time; otherwise at whichever time funding becomes available after five years from the present.

Methods for monitoring and review of these guidelines must have a low cost, and involve landholders to the extent necessary but not impose greatly on their time and resources. Dedicated funding may be required for monitoring and review actions.

Pink-eared Ducks & Eurasian Coots in the PTRCW

Photo by A. Briggs

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