



Appendix E

Box gum woodlands analysis



Narrabri Gas Project

Box Gum Woodlands Analysis

Prepared for
Santos NSW (Eastern) Pty Ltd

February 2018



This report should be cited as 'Eco Logical Australia (2018). *Narrabri Gas Project Box Gum Woodlands Analysis*. Prepared for Santos NSW (Eastern) Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd

Disclaimer

This document may only be used for the purpose for which it was commissioned and in accordance with the contract between Eco Logical Australia Pty Ltd and Santos NSW (Eastern) Pty Ltd. The scope of services was defined in consultation with Santos NSW (Eastern) Pty Ltd, and the availability of reports and other data on the subject area. Changes to available information, legislation and schedules are made on an ongoing basis and readers should obtain up to date information.

Eco Logical Australia Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report and its supporting material by any third party. Information provided is not intended to be a substitute for site specific assessment or legal advice in relation to any matter. Unauthorised use of this report in any form is prohibited.

Template 12/09/13

Contents

Executive summary	vi
1 Introduction	1
1.1 Background.....	1
1.2 Purpose of report.....	1
2 Environmental setting	2
2.1 Climate.....	2
2.2 Geology.....	2
2.3 Mitchell landscapes.....	5
2.4 Soil fertility.....	8
3 Methods and results	10
3.1 Vegetation surveys.....	10
3.2 Soil classification.....	10
3.3 Bohena Creek inspection.....	11
3.4 Results.....	11
4 NSW Biodiversity Conservation Act 2016	17
4.1 Introduction.....	17
4.2 Vegetation mapping.....	17
4.2.1 Namoi CMA mapping.....	17
4.2.2 NSW Vegetation Classification and Assessment.....	18
4.3 Scientific Committee Final Determination.....	20
4.4 Characteristic species analysis.....	28
4.4.1 Overall plot data.....	28
4.4.2 Percentage of characteristic species from the Final Determination.....	30
4.4.3 Percentage of native species that are characteristic species from the Final Determination.....	35
4.5 Profiles, fact sheets and guidelines.....	37
4.5.1 Office of Environment and Heritage profile.....	37
4.5.2 Fact sheet.....	37
4.5.3 Identification guidelines.....	37
4.5.4 Field identification guidelines.....	39
4.6 Conclusion.....	39
5 Environment Protection and Biodiversity Conservation Act 1999	40
5.1 Introduction.....	40
5.2 Listing advice.....	40
5.3 Policy statement and species list.....	47

5.4	Review of Milledge (2012).....	48
5.5	Conclusion.....	48
6	Conclusion.....	49
	References.....	50
	Appendix A: Plot species list.....	53
	Appendix B: BC Act list of characteristic species.....	59
	Appendix C: Sample site photos.....	82

List of figures

Figure 1: Geology.....	4
Figure 2: Mitchell Landscapes.....	7
Figure 3: Soil fertility.....	9
Figure 4: Subject plots.....	15
Figure 5: Bohena Creek Rapid Sites.....	16
Figure 6: Study area.....	19

List of tables

Table 1: Geology.....	2
Table 2: Mitchell Landscapes.....	5
Table 3: Fertility.....	8
Table 4: Subject plots.....	11
Table 5: Scientific Committee Final Determination.....	20
Table 6: Plot data percentages.....	29
Table 7: Plot data species analysis.....	30
Table 8: Plots with relatively higher percentages of native species that are characteristic species.....	35
Table 9: General description comparison.....	40
Table 10: Plot species list.....	53

Table 11: BC Act list of characteristic species	59
---	----

Abbreviations

Abbreviation	Description
BBS	Brigalow Belt South
BC Act	NSW Biodiversity Conservation Act 2016
CMA	Catchment Management Authority
CEEC	Critically Endangered Ecological Community
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
EEC	Endangered Ecological Community
ELA	Eco Logical Australia
EPBC Act	Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>
NPWS	National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage
RVC	Regional Vegetation Community
TSC Act	Former NSW <i>Threatened Species Conservation Act 1995</i>
VCA	Vegetation Classification and Assessment

Executive summary

This report presents an assessment as to whether *White Box Yellow Box Blakely's Red Gum Woodland / White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* occurs within the study area for the Narrabri Gas Project. This ecological community is listed as an Endangered Ecological Community (EEC) under the New South Wales (NSW) *Biodiversity Conservation Act 2016* (BC Act) (formerly NSW *Threatened Species Conservation Act 1995* (TSC Act)) and as a Critically Endangered Ecological Community (CEEC) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Recent submissions on the Environmental Impact Statement (EIS) for the Narrabri Gas Project, and a previous flora and fauna study (Milledge 2012) undertaken in the study area claimed that *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland / White Box Yellow Box Blakely's Red Gum Woodland* was present at four locations. However, no differentiation was made between the state and federal listings and the methodology used to identify this community is not considered adequate.

Therefore, to determine whether the listed community occurs within the study area the data from 16 subject plots located in vegetation dominated or co-dominated by *Eucalyptus blakelyi* (Blakely's Red Gum) was analysed and compared to the NSW Scientific Committee Final Determination under the BC Act and the listing advice and policy statement for the community under the EPBC Act. This analysis included a review of literature cited in the Final Determination and listing advice, and compares the data in the subject plots with the list of characteristic species in the Final Determination, with over 90 other plots undertaken in the study area from 2011 to 2013. It also included an assessment of soil and geology, landscape and vegetation mapping data with reference to other vegetation mapping projects and the literature cited in the Final Determination and EPBC Act listing advice.

White Box Yellow Box Blakely's Red Gum Woodland (BC Act) was found not to be present in the study area because the assemblage of species and soil type was not consistent with that found in the Final Determination. Specifically, the subject plots contained a low number and frequency of characteristic species. In addition, most of the characteristic species recorded in the subject plots also occurred in higher frequencies in other vegetation communities in the study area. The location and type of vegetation community in which the subject plots were located was, therefore, considered not to be consistent with that part of the listed community dominated by *E. blakelyi* (Blakely's Red Gum) or with the similar descriptions of this community in the literature. Instead the *E. blakelyi* woodland as assessed by the plot data conformed to *Red gum – Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion* which is restricted in extent but not threatened (Benson et al. 2010).

White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (EPBC Act) was also found not to be present in the study area because the assemblage of species and soil type was not consistent with the general description of this community in the listing advice and cited literature.

It is also noted Milledge (2012) incorrectly applied the EPBC Act condition class criteria to identify the presence of the listed community. Instead, these criteria should be applied to vegetation that has already been identified as the correct vegetation community to determine if it has sufficient value to be the listed community.

In response to the submissions on the Environmental Impact Statement, a further inspection of seven discreet localities along Bohena Creek was undertaken to determine the presence or absence of

Eucalyptus melliodora (Yellow Box). Based on the results of surveys undertaken in the study area over more than four years, including the recent inspection of Bohena Creek, it is considered likely that *Eucalyptus melliodora* either does not occur in the study area, or occurs at such a low abundance to be meaningless in terms of plant community composition and identification of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland / White Box Yellow Box Blakely's Red Gum Woodland*.

In summary it is concluded that *White Box Yellow Box Blakely's Red Gum Woodland / White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* does not occur in the study area.

It is however acknowledged that areas of *White Box Yellow Box Blakely's Red Gum Woodland / White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* such as *Eucalyptus melliodora* (Yellow Box) on alluvial terraces and *E. albens* (White Box) grassy woodland are likely to occur within the Pilliga Forest outside of the study area.

1 Introduction

1.1 Background

This report presents an assessment as to whether *White Box Yellow Box Blakely's Red Gum Woodland / White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* occurs within the study area for the Narrabri Gas Project. This ecological community is listed as an Endangered Ecological Community (EEC) under the New South Wales (NSW) *Biodiversity Conservation Act 2016* (BC Act) (formerly NSW *Threatened Species Conservation Act 1995* (TSC Act)) and as a Critically Endangered Ecological Community (CEEC) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Under the BC Act the title of this community is:

- *White Box Yellow Box Blakely's Red Gum Woodland.*

Under the EPBC Act the title of this community is:

- *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

A flora and fauna report by Milledge (2012) stated that targeted surveys across their study area (including part of the study area for the Narrabri Gas Project) resulted in the identification of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (EPBC Act) and *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) at four locations. Both listings under the EPBC Act and BC Act are indicated as being present at all four sites and no mention is made of the differentiation between the EPBC Act listing and the BC Act listing. Recent submissions on the Environmental Impact Statement (EIS) continue to claim the presence of this community in the study area.

A table of floristic data is presented in Appendix 2 of Milledge (2012) for all four sites and mentions two 'qualifying criteria' under the EPBC Act listing. These criteria are parts of a flow chart in the EPBC Act Policy Statement (DEH 2006a) for this community, which in turn is based on the listing advice for this community under the EPBC Act as a CEEC. Milledge (2012) only provides point locations of surveys and does not map the extent of this vegetation community.

Due to the lack of mapping and consideration of other relevant information regarding both the EPBC Act and BC Act listing and the availability of more plot information, further analysis is required to adequately determine if this community occurs within the study area.

1.2 Purpose of report

The purpose of this report is to present the results of an analysis aimed to determine whether *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) and /or *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (EPBC Act) occurs within the study area for the Narrabri Gas Project.

This analysis is undertaken with reference to data collected in the field over more than four years and analysis of this data with reference to relevant state and federal listing information, guidelines and policies regarding this community.

2 Environmental setting

The types of organisms (flora and fauna) in terrestrial ecosystems are determined by the local and regional climate, the topography (slope, elevation and aspect which affects the local climate and the soil), the geology and soil, the other organisms in the area, and the history of disturbance events (El-Shaarawi & Piegorsch 2002).

Similarly, the soil is determined by the climate, vegetation, topography/geology, animals/microbes, and time since disturbance. The presence of animals and microbes are determined by plants, climate, soil and vegetation. Microclimates, and some aspects of regional climate, are determined by vegetation and topography (El-Shaarawi & Piegorsch 2002).

2.1 Climate

The study area is located within the Brigalow Belt South Bioregion, which lies within an ecological gradient, or ecotone, between the dry inland or Eyrean zone and the wetter coastal or Bassian zone. Within the south eastern section of the bioregion where the study area is located, the climate is classed as subhumid: there is no dry season and the area experiences hot summers.

Substantial rainfall can occur at any time of the year but there is a peak in summer and a smaller peak in winter. In summer, high intensity rain or thunderstorms can cause significant erosion. Evaporation rates are high in summer and often exceed precipitation rates, so the net penetration of rainfall is greater in winter than in summer (NPWS 2000). Mean annual rainfall in the NSW section of the Brigalow Belt South Bioregion varies from 550 mm in the west (in Gilgandra) to 823 mm on the east of the bioregion (at Murrurundi). On the north-south gradient, mean annual rainfall is 587 mm in Dubbo, 651 mm at Narrabri, and 659 mm on the Queensland border (at Texas).

Temperatures vary with altitude throughout the bioregion and have large daily variation (daily maximum can reach 45 °C in summer and stay above 40 °C for several days, and minimum temperatures can be as low as -9 °C). However, mean monthly temperatures (based on 6 weather stations in NSW) range from a maximum of 33 °C in January to a minimum of 3 °C in July (NPWS 2000).

2.2 Geology

The geology of the study area has been mapped at a 1:250,000 scale by the NSW Department of Mineral Resources (DMR) (2003). Seven main geological units have been mapped (**Table 1** and **Figure 1**).

Table 1: Geology

Unit name	Description	Period	Dominant lithology	Location in respect to the study area
unnamed	Clayey alluvium often gilgaid.	Quaternary	alluvium	North-western portion north of the Pilliga Forest.
Keelindi beds	Colluvial polymictic gravel, sand, silt and clay; may include some eluvial in situ regolith deposits. Overlies off-white, fine to coarse grained, poorly to well sorted, quartzose sandstone,	Cretaceous	sandstone, conglomerate	Central portion in a broad north-east to south-west band downslope of Pilliga Sandstone.

Unit name	Description	Period	Dominant lithology	Location in respect to the study area
	pebbly sandstone and conglomerate interbedded with minor shale.			
unnamed	Interpreted clay, silt, sand, gravel.	Quaternary	clay, silt, sand, gravel	Along the floodplain of major creeks (e.g. Bohena Creek) and tributaries.
Pilliga Sandstone	Medium to very coarse grained, well sorted, angular to subangular quartzose sandstone. Minor interbeds of mudstone, siltstone and fine grained sandstone and coal. Common carbonaceous fragments and iron staining. Rare lithic fragments. Large scale tabular.	Jurassic	sandstone	Eastern portion in a broad roughly north-south band associated with sandstone outcropping along the eastern escarpment of the Pilliga Forest.
unnamed	Texture contrast soils with sand predominating at the surface.	Quaternary	sand	Central west within and north of the Pilliga Forest.
unnamed	Unconsolidated sand.	Quaternary	sand	Small area in the north restricted to Yarrie Lake.
unnamed	Unconsolidated silt and clay, minor sand. Commonly carbonaceous and flat to cross laminated.	Quaternary	silt, clay	Confined to Bohena Creek.

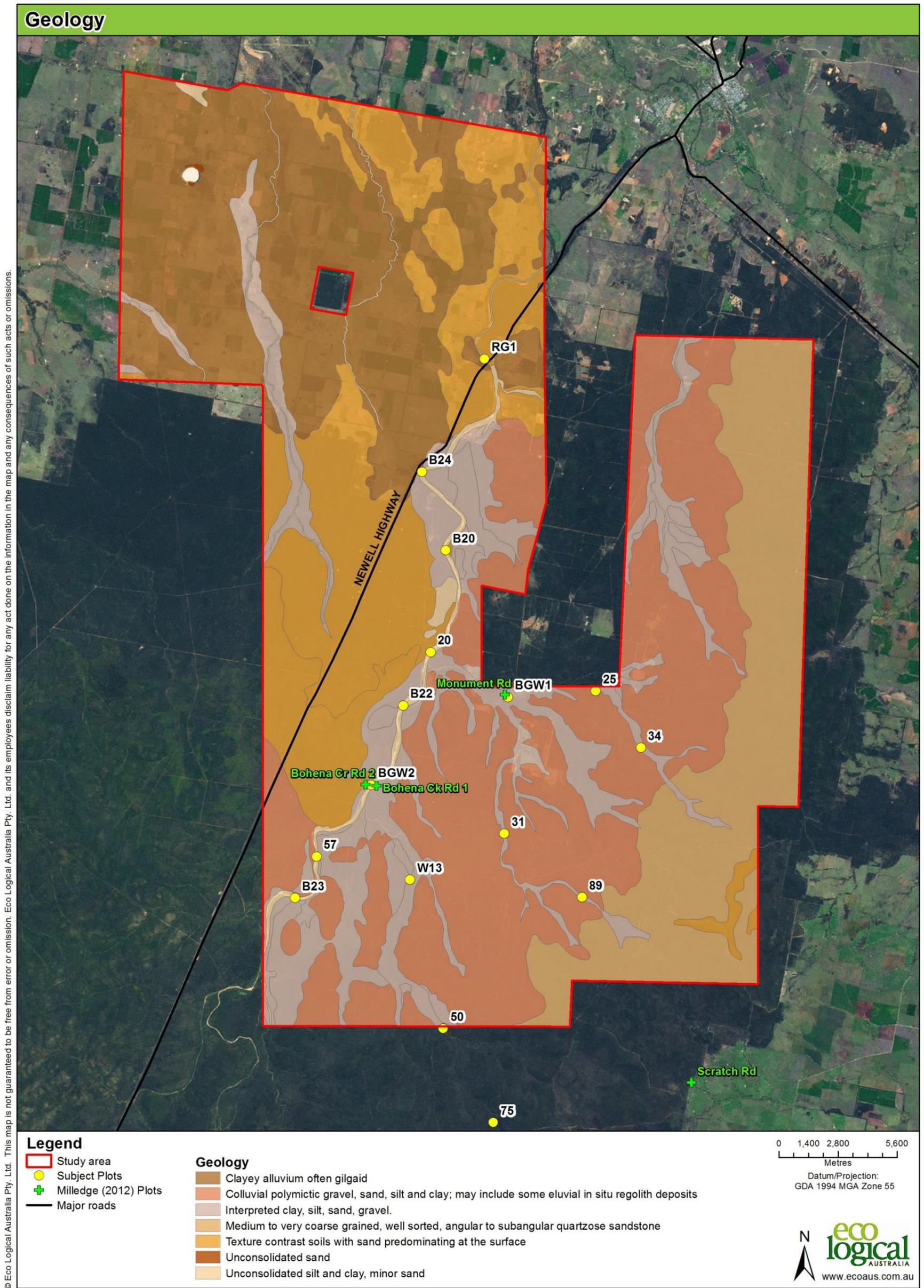


Figure 1: Geology

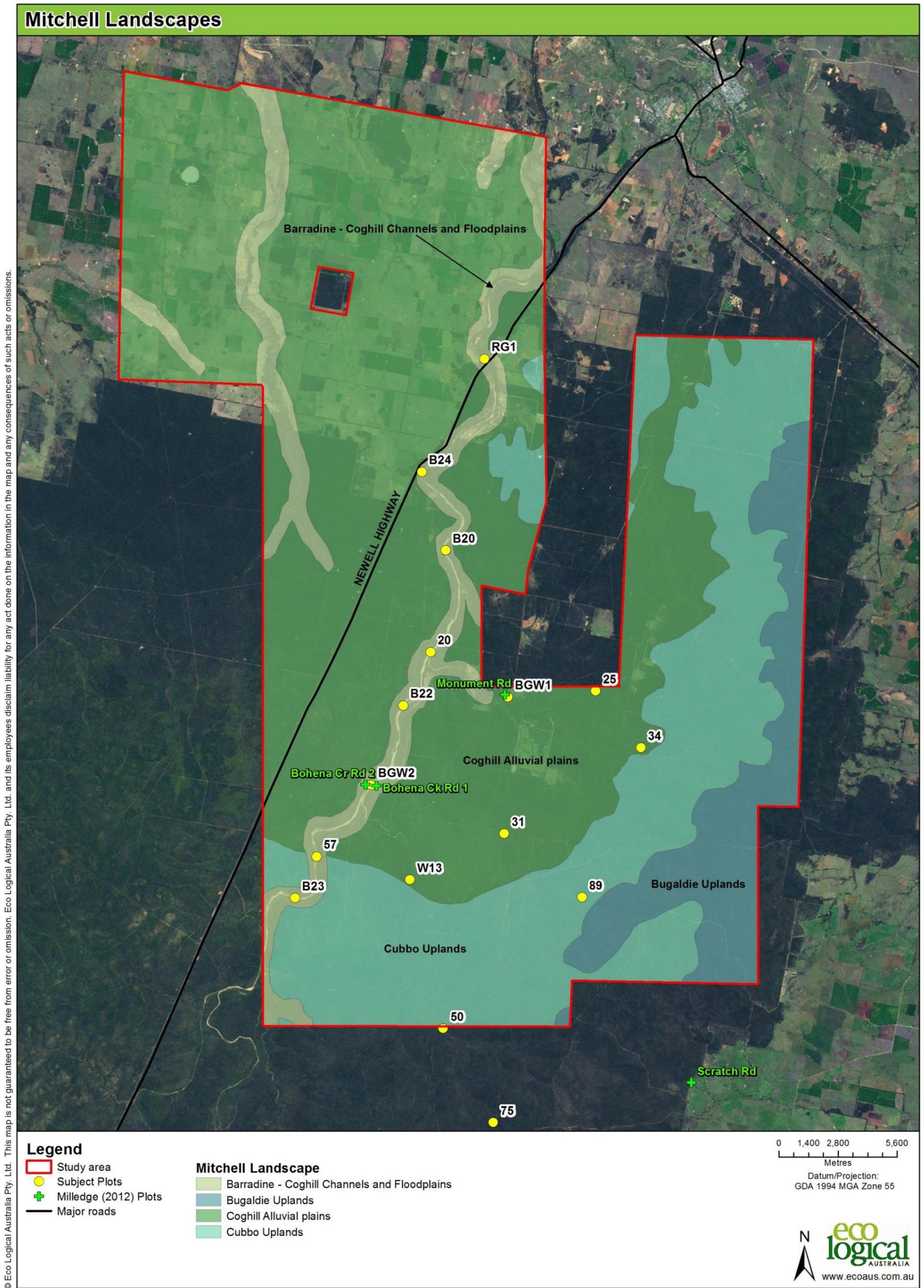
2.3 Mitchell landscapes

Mitchell Landscapes are a system of ecosystem classification mapped at a 1:250,000 scale, based on a combination of soils, topography and vegetation (DECC 2008). Mitchell Landscapes are used in regional conservation planning in NSW and form an important component of the Biodiversity Assessment Method under the BC Act. The study area consists of four Mitchell Landscapes as outlined in **Table 4** and **Table 2**.

Table 2: Mitchell Landscapes

Mitchell Landscape	Landscape Description	Location in respect to the study area
Baradine - Coghill Channels and Floodplains	<p>Sandy incised channels and distributary streams on Quaternary alluvium in fans of Coghill and Baradine Creeks flowing from the sandstones of the Pilliga Forest.</p> <p>General elevation 170 to 210 m, local relief 10 m.</p> <p>Deep texture-contrast soils with harsh clay subsoils, grey clay with gilgai and uniform deep yellow sands. Sediments and soils become finer down valley merging with the Coghill Alluvial Plains ecosystem.</p> <p>Gallery woodland dominated by <i>Eucalyptus camaldulensis</i> (River Red Gum) along the channels. Other species including; <i>E. populnea</i> (Bimble Box), <i>E. pilligaensis</i> (Pilliga Box), <i>E. blakelyi</i> (Blakely's Red Gum), <i>Callitris glaucophylla</i> (White Cypress Pine) and <i>E. sideroxylon</i> (Mugga Ironbark) and occasional <i>E. melanophloia</i> (Silver-leaved Ironbark).</p>	Along the floodplain of major creeks (e.g. Bohena Creek) and tributaries.
Coghill Alluvial Plains	<p>Distal parts of the Quaternary alluvial fans largely derived from Jurassic quartz sandstone on streams draining from the Pilliga Forests. Long gentle slopes broken by sandy abandoned stream channels (sand monkeys), patches of heavy grey clay, and contemporary incised stream channels.</p> <p>General elevation 200 to 280 m, local relief 5 to 9 m.</p> <p>Deep texture-contrast soils with harsh clay subsoils, grey clay with gilgai.</p> <p>Open forest of <i>C. glaucophylla</i>, <i>E. populnea</i>, <i>E. pilligaensis</i>, <i>E. blakelyi</i> and <i>E. sideroxylon</i>. <i>Corymbia trachyphloia</i> (Brown Bloodwood) and <i>Xanthorrhoea</i> sp. (Grass Trees) on sand monkeys. Patches of <i>Allocasuarina luehmannii</i> (Bull Oak) or <i>Acacia harpophylla</i> (Brigalow) on gilgai in heavy clay. <i>E. chloroclada</i> (Dirty Gum) and <i>E. camaldulensis</i> in creek lines.</p>	Central portion within and north of the Pilliga Forest.
Cubbo Uplands	<p>Pilliga horizontal Jurassic quartz sandstones, limited shales, tertiary basalt caps and plugs plus the sediments derived from these rocks. Stepped sandstone ridges with low cliff faces and high proportion of rock outcrop. Long gentle outwash slopes intersected by sandy streambeds and prior stream channels. A few patches of heavy clay.</p> <p>General elevation 400 to 550 m, local relief 50 m.</p> <p>On sandstone, the ridge tops have thin discontinuous soils with stony, sandy profiles and low nutrients. Down slope texture-contrast soils are more common typically with harsh clay subsoils and in the valley floors sediments tend to be sorted into deep sands with yellow earthy profiles, harsh grey clays, or more texture-contrast soils with a greater concentration of soluble salts.</p>	Central eastern portion in a broad north-east to south-west band downslope of Bugaldie Uplands.

Mitchell Landscape	Landscape Description	Location in respect to the study area
	<p>The sandstone outcrop areas support various forests and woodlands including; <i>E. nubila</i> (Blue-leaved Ironbark), <i>E. rossii</i> (Inland Scribbly Gum), <i>C. endlicheri</i> (Black Cypress Pine), <i>Atalaya hemiglauca</i> (Whitewood), and <i>Angophora floribunda</i> (Rough-Barked Apple).</p> <p>Stony hills in the north of the region carry mallee patches with <i>E. melanophloia</i>, <i>Corymbia maculata</i> (Spotted Gum) [sic], and <i>A. leiocarpa</i> (Smooth-barked Apple).</p> <p>Gentler sandstone slopes over most of the region carry; <i>E. crebra</i> (Narrow-leaved Ironbark), <i>C. glaucophylla</i>, <i>E. macrorhyncha</i> (Red Stringybark), patches of <i>E. viridis</i> (Green Mallee) and <i>Melaleuca uncinata</i> (Broombush) heath.</p> <p>In western and northern sections on texture-contrast or more uniform harsh clay soils forests of <i>E. pilligaensis</i>, <i>E. microcarpa</i> (Grey Box), <i>E. populnea</i>, and <i>E. conica</i> (Fuzzy Box) are found with stands of <i>Allocasuarina luehmannii</i>, <i>Alectryon oleifolium</i> (Rosewood), <i>Atalaya hemiglauca</i>, <i>Geijera parviflora</i> (Wilga), <i>Casuarina cristata</i> (Belah), <i>Acacia homalophylla</i> (Yarran), and <i>Eremophila mitchellii</i> (Budda).</p>	
Bugaldie Uplands	<p>Stepped stony ridges on Jurassic quartz sandstone with some conglomerate, shale and occasional interbedded basaltic volcanic rocks.</p> <p>General elevation 350 to 490 m local relief 50 to 150 m, extensive joint controlled stream network.</p> <p>Abundant outcrop on ridge tops with thin discontinuous soils with stony, sandy profiles and low nutrients. Down slope texture-contrast soils are more common typically with harsh clay subsoils and deep uniform or gradational yellow-brown sands on the valley floors.</p> <p>Patches of <i>E. viridis</i> and <i>E. dumosa</i> (White Mallee), clumps of <i>Acacia concurrens</i> (Currah) and <i>Acacia cheelii</i> (Motherumbah) amongst <i>E. sideroxylon</i> and <i>C. endlicheri</i> with shrubby understorey including <i>Grevillea floribunda</i> (Rusty Spider Flower), <i>Prostanthera</i> spp. (Mint Bush), <i>Stypantra glauca</i> (Nodding Blue Lily) and <i>Cheilanthes sieberi</i> (Rock Fern) on ridges and stony slopes.</p> <p><i>E. crebra</i>, <i>E. macrorhyncha</i>, <i>C. endlicheri</i>, <i>Corymbia trachyphloia</i> and <i>A. floribunda</i> on the sandy flats. <i>E. albens</i> (White Box) and <i>Ficus rubiginosa</i> (Port Jackson Fig) on the volcanics.</p>	Eastern portion in a broad roughly north-south band associated with sandstone outcropping along the eastern escarpment of the Pilliga Forest



© Eco Logical Australia Pty. Ltd. This map is not guaranteed to be free from error or omission. Eco Logical Australia Pty. Ltd. and its employees disclaim liability for any act done on the information in the map and any consequences of such acts or omissions.

Figure 2: Mitchell Landscapes

2.4 Soil fertility

Estimated inherent fertility of soils in the New England/North West Strategic Regional Land use area (including the study area) was mapped by the NSW Office of Environment and Heritage (OEH) (2013) at a 1:100,000 to 1:250,000 scale.

The mapping describes soil fertility according to a five class system:

- Low (1)
- Moderately low (2)
- Moderate (3)
- Moderately high (4)
- High (5)

Fertility values are assigned to dominant soil types from which a fertility value was derived (for example lightly textured alluvial soils are classified as moderately low fertility).

Three fertility classes have been mapped in the study area (**Table 3** and **Figure 3**)

Table 3: Fertility

Class	Location in respect to the study area
Low	Scattered occurrences in the east and central portions
Moderately Low	Dominant class located across the southern, central, and eastern portions within the Pilliga Forest, extending north along Bohena Creek and other major drainage lines
Moderate	North-west of the Pilliga Forest

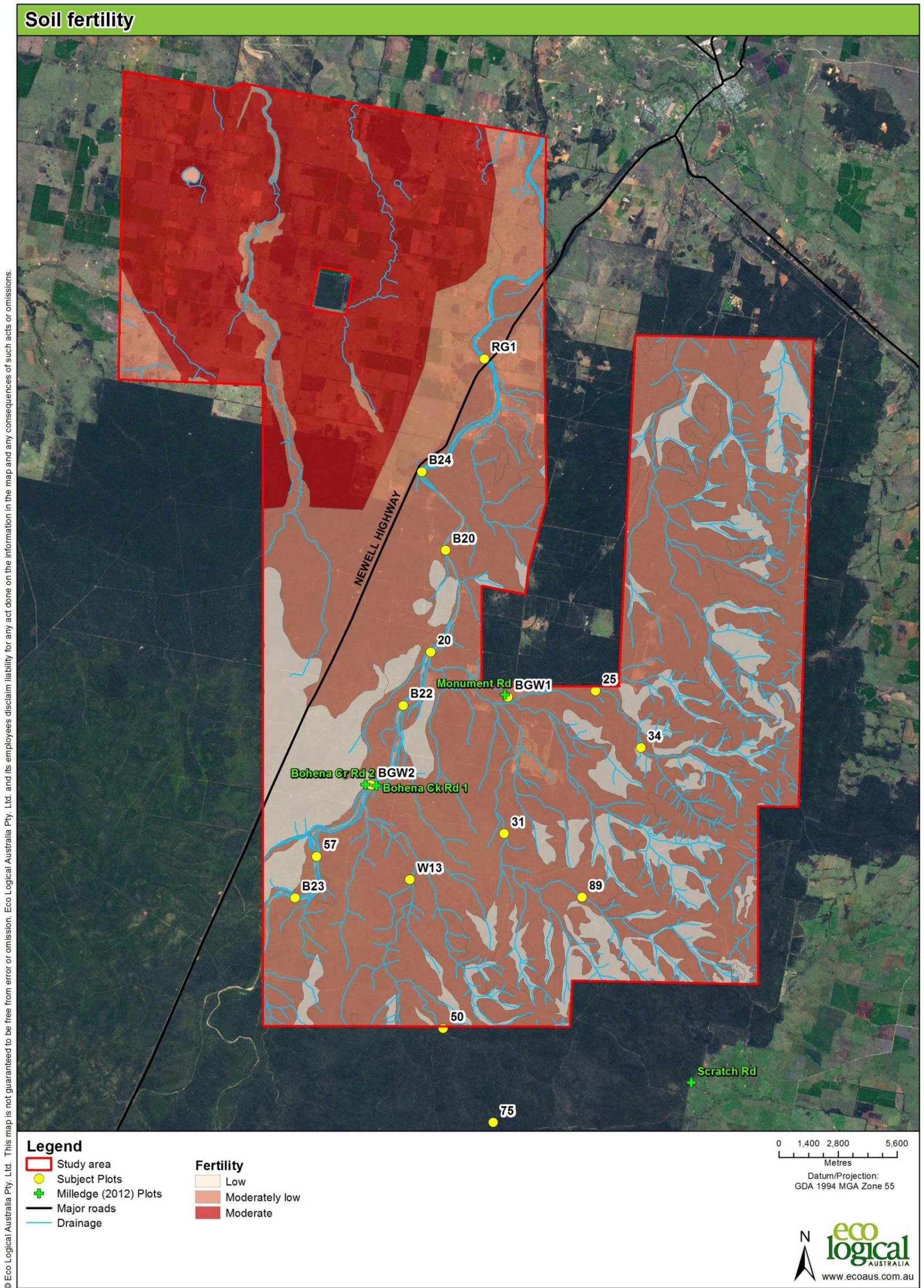


Figure 3: Soil fertility

3 Methods and results

3.1 Vegetation surveys

Vegetation surveys have been undertaken in the study area during different climactic and seasonal conditions over more than four years. Surveys included recording the presence/absence or the cover/abundance of all observed vascular flora species in a series of 20 x 20 m (0.04 ha) and 20 x 50 m (0.1 ha) plots. Cover/abundance was recorded according to the following scale:

- + = few, small cover (<5%)
- r = solitary, small cover (<5%)
- 1 = numerous (<5%)
- 2 = 5-25%
- 3 = 25-50%
- 4 = 50-75%
- 5 = <75%

Sixteen plots are located in vegetation that has either been stated as being *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (EPBC Act) and *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) by Milledge (2012) or that were seen as having potential to be this community because they contained *Eucalyptus blakelyi* (Blakely's Red Gum), a characteristic canopy species of the community.

Vegetation mapping has been continually updated within the study area by Eco Logical Australia (ELA) since 2010. This Plant Community Type mapping is based on vegetation survey and ground-truthing data, LiDAR analysis, aerial photograph interpretation and consideration of vegetation profiles from Benson et al. (2010) and other vegetation data sets including the Namoi Catchment Management Authority (CMA) mapping (ELA 2009). Vegetation in all of the 16 subject plots has been mapped by ELA as *Red gum – Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion*.

3.2 Soil classification

Soil texture was measured in the field at eight of the sixteen subject plots. At each site a sample of soil was collected with particles >2 mm (gravel, roots and other organic material) removed. The sample was then moistened and kneaded into a bolus. The bolus was continually worked (adding more soil and water as necessary) for approximately 1-2 minutes until there was no apparent change in plasticity.

A ribbon was then extruded by shearing the sample between thumb and forefinger. The length of the ribbon produced was then measured. The combination of the behaviour of the moist bolus and the ribbon length was then used to give an indication of the field texture grade (McDonald et al. 1998).

Soil colour of each sample was also measured using the Munsell Colour System. A dry soil sample was compared with pages from the Munsell colour book that closely corresponded to the colour of the sample. The closest match was then determined. The soil sample was then moistened and the closest match for the wet sample was determined.

3.3 Bohena Creek inspection

Submissions on the Environmental Impact Assessment (EIS) raised concerns that *Eucalyptus melliodora* (Yellow Box) was present in the study area, generally scattered and with low density, though was found to be dominant in some patches of Bohena/Borah Creeks.

Eucalyptus melliodora was not recorded in any of the 327 vegetation plots undertaken as part of the EIS. A known hybrid between *Eucalyptus melliodora* and *Eucalyptus sideroxylon* (Mugga Ironbark) was identified in the study area, however its distribution does not align with riparian areas and is restricted to Broombush Shrubland adjoining the Newell Highway.

In response to the submissions on the EIS, a further inspection of seven discreet localities along Bohena Creek (**Figure 5**) was undertaken between 24 and 26 October 2017 to determine the veracity of the claim of presence of *Eucalyptus melliodora*. The inspection involved traversing the length of Bohena Creek (within the study area) in a vehicle, observing the vegetation and collecting rapid site data points. At each of the seven discreet localities a number of rapid site points were collected (a total of 25 individual points) to cover the variety of PCTs present across the width of Bohena Creek and its floodplain. Data recorded at each point included canopy species, canopy cover, PCT code, soil texture, fire history, condition, landform element and pattern, notes, surveyor, date and a photograph.

3.4 Results

The subject plot numbers and soil classifications are shown in **Table 4** and the locations of these plots are shown in **Figure 4**. The locations that Milledge (2012) identified as *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (EPBC Act) and *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) are also shown in **Figure 4**.

A species list for each plot is included in **Appendix A**. The list of species from the Final Determination that characterises *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) is provided in **Appendix B**.

Table 4: Subject plots

Subject plot	Date surveyed	Data type collected	Soil colour / texture	Inherent fertility
57	January 2011	Presence/absence	~	~
75	January 2011	Presence/absence	~	~
89	January 2011	Presence/absence	~	~
50	January 2011	Presence/absence	~	~
20	January 2011	Presence/absence	~	~
25	January 2011	Presence/absence	~	~
31	January 2011	Presence/absence	~	~
34	January 2011	Presence/absence	~	~
BGW 1	October 2013	Cover/abundance and soil classification	Light brown fine textured loamy sand [#]	Moderately low
BGW 2	October 2013	Cover/abundance and soil classification	Light brown fine textured loamy sand [#]	Moderately low / Low

Subject plot	Date surveyed	Data type collected	Soil colour / texture	Inherent fertility
			overlain with coarse alluvial sand ^{##}	
W13	October 2013	Cover/abundance	~	~
RG1	November 2013	Cover/abundance and soil classification	Brown to dark brown loamy sand [#] overlain with coarse yellow alluvial sand ^{##} (loam)	Moderately low / Low
B24	November 2013	Cover/abundance and soil classification	Brown loamy sand [#]	Moderately low
B23	November 2013	Cover/abundance and soil classification	Light yellowish -brown loamy sand [#]	Moderately low
B22	November 2013	Cover/abundance and soil classification	Brown loamy sand [#]	Moderately low
B20	November 2013	Cover/abundance and soil classification	Light yellowish brown loamy sand [#]	Moderately low

[#] Loamy sand has slight coherence; sand grains of medium size, can be sheared between thumb and forefinger to give a minimal ribbon of about 5 mm and has an approximately clay content of 5%.

^{##} Sand has nil to very slight coherence, cannot be moulded, sand grains of medium size and has an approximate clay content of commonly <5%.

Despite driving the length of Bohena Creek within the study area, undertaking targeted searches at seven discrete localities including the collection of data at 25 rapid sites, *Eucalyptus melliodora* was not located. The results of the inspection are contained in **Table 5**. The most common canopy species recorded were *Eucalyptus chloroclada* (Dirty Gum), *Eucalyptus blakelyi* (Blakely's Red Gum), *Angophora floribunda* (Rough-barked Apple) and *Callitris glaucophylla* (White Cypress Pine). *Eucalyptus conica* (Fuzzy Box) was recorded at four locations. It is considered highly likely that hybridisation between *Eucalyptus blakelyi*, *Eucalyptus chloroclada* and *Eucalyptus camaldulensis* (River Red Gum) is occurring along the length of Bohena Creek as evidenced by intermediate bud and fruit characteristics.

Two of the canopy species observed may superficially appear similar to *Eucalyptus melliodora*, particularly *Eucalyptus chloroclada* which has a rough yellowish bark stocking and *Eucalyptus conica* which has box-like bark, however anything more than a casual inspection would quickly reveal these species not to be *Eucalyptus melliodora*.

Based on the results of field surveys over more than four years in the study area, including this recent inspection of Bohena Creek, it is considered likely that *Eucalyptus melliodora* either does not occur in the study area, or occurs at such a low abundance to be meaningless in terms of plant community composition and identification of EECs.

Table 5: Bohena Creek inspection results

Canopy species	Canopy Cover	PCT Code	Soil Texture	Date	Easting	Northing
<i>Eucalyptus blakelyi</i> / <i>Eucalyptus chloroclada</i> (likely hybrid)	30	399	Sand	24-Oct-17	745822	6600124

Canopy species	Canopy Cover	PCT Code	Soil Texture	Date	Easting	Northing
<i>Eucalyptus conica, Eucalyptus chloroclada</i>	25	202	Loamy Sand	24-Oct-17	745712	6600171
<i>Angophora floribunda, Eucalyptus chloroclada</i>	20	401	Sand	24-Oct-17	745906	6600278
<i>Angophora floribunda, Eucalyptus chloroclada</i>	20	401	Sand	24-Oct-17	745966	6601193
<i>Eucalyptus chloroclada/Eucalyptus blakelyi</i> (likely hybrid), <i>Angophora floribunda</i>	15	399	Sand	25-Oct-17	746024	6601153
<i>Angophora floribunda, Eucalyptus chloroclada</i>	15	401	Sand	25-Oct-17	746101	6601155
<i>Angophora floribunda, Eucalyptus chloroclada</i>	25	401	Sand	25-Oct-17	746152	6601154
<i>Eucalyptus conica</i>	30	202	Sandy Loam	25-Oct-17	748552	6605182
<i>Eucalyptus conica, Angophora floribunda</i>	20	202	Sandy Loam	25-Oct-17	748525	6604920
<i>Eucalyptus chloroclada/Eucalyptus blakelyi/Eucalyptus camaldulensis</i> (likely hybrid)	5	399	Sand	25-Oct-17	748381	6604926
<i>Angophora floribunda, occasional Eucalyptus chloroclada,</i>	25	401	Loamy Sand	25-Oct-17	748312	6604929
<i>Eucalyptus chloroclada/Eucalyptus blakelyi/Eucalyptus camaldulensis</i> (likely hybrid)	10	399	Sand	25-Oct-17	748433	6605261
<i>Angophora floribunda, Eucalyptus chloroclada</i>	20	401	Loamy Sand	25-Oct-17	748364	6605259
<i>Angophora floribunda,</i>	20	401	Loamy Sand	25-Oct-17	750285	6607041
<i>Eucalyptus chloroclada/Eucalyptus blakelyi</i> (likely hybrid)	5	399	Sand	25-Oct-17	750190	6607127
<i>Angophora floribunda, Eucalyptus chloroclada</i>	10	401	Loamy Sand	25-Oct-17	750091	6607198
<i>Angophora floribunda, Eucalyptus chloroclada, Callitris glaucophylla</i>	10	401	Sand	25-Oct-17	750739	6607488
<i>Eucalyptus chloroclada/Eucalyptus blakelyi</i> (likely hybrid)	10	399	Sand	25-Oct-17	750774	6607476

Canopy species	Canopy Cover	PCT Code	Soil Texture	Date	Easting	Northing
<i>Eucalyptus blakelyi/Eucalyptus chloroclada</i> (likely hybrid), <i>Angophora floribunda</i>	0	399	Sand	25-Oct-17	750450	6607535
<i>Angophora floribunda, Eucalyptus chloroclada, Callitris glaucophylla</i>	20	401	Sand	25-Oct-17	750298	6607579
<i>Eucalyptus blakelyi/Eucalyptus chloroclada, Angophora floribunda, Eucalyptus conica</i>	10	399	Sand	25-Oct-17	753390	6613654
<i>Angophora floribunda, Eucalyptus blakelyi, Callitris glaucophylla</i>	15	399	Sand	25-Oct-17	753442	6613645
<i>Eucalyptus chloroclada, Angophora floribunda, Callitris glaucophylla</i>	15	401	Sand	25-Oct-17	755119	6617711
<i>Angophora floribunda, Callitris glaucophylla</i>	30	401	Sand	26-Oct-17	756401	6628723
<i>Eucalyptus blakelyi</i>	15	399	Sand	26-Oct-17	756452	6628782

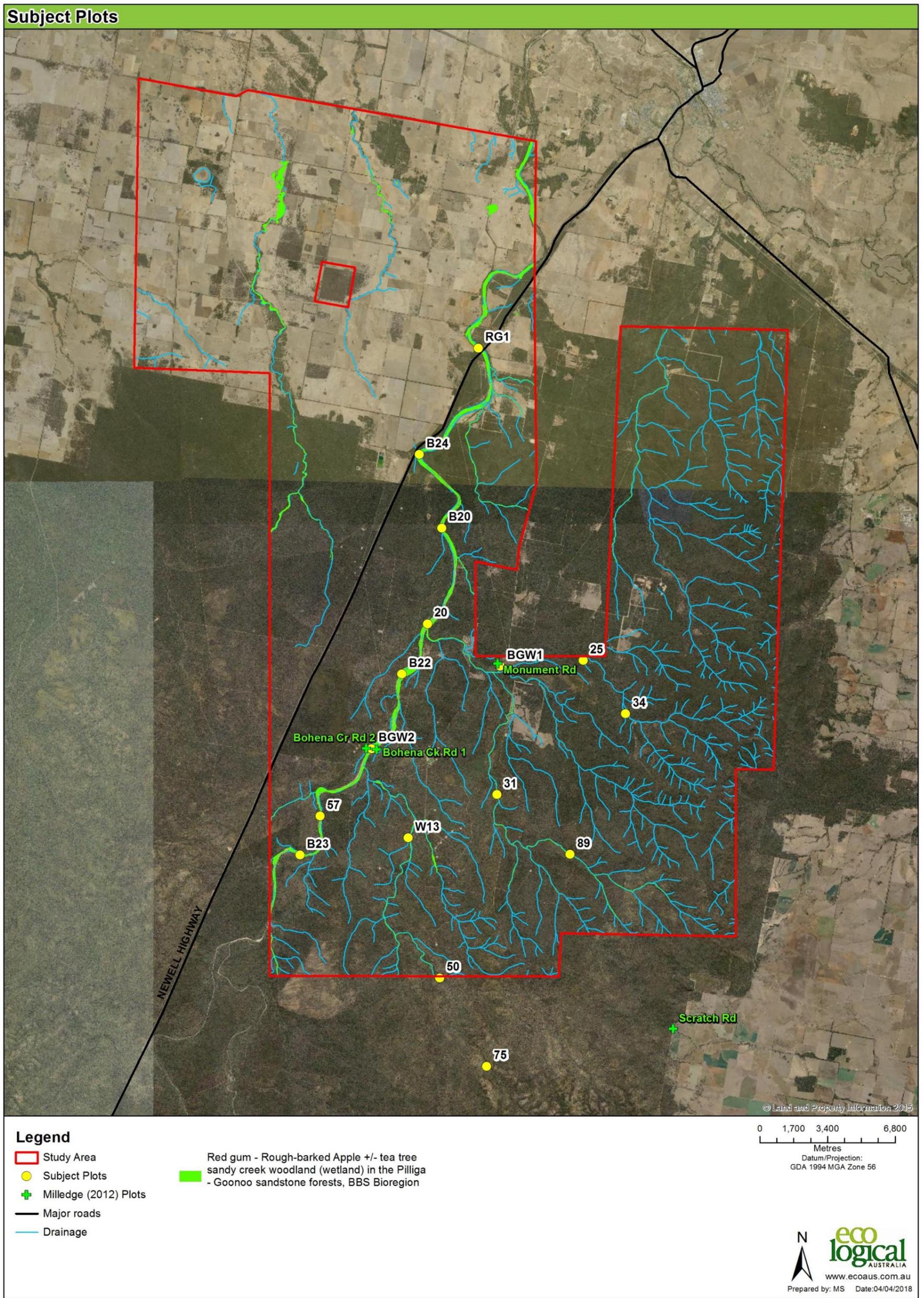


Figure 4: Subject plots

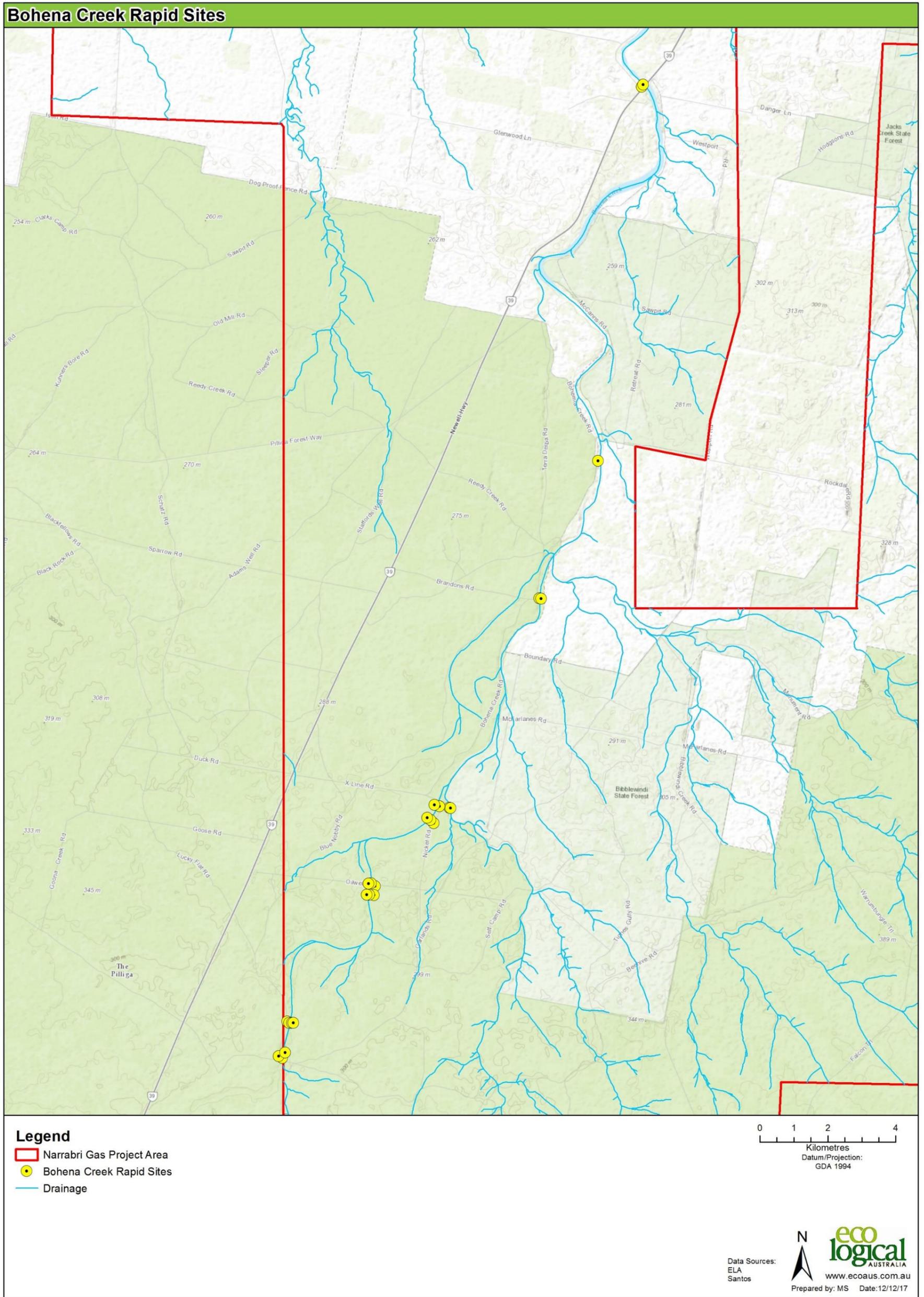


Figure 5: Bohena Creek Inspection

4 NSW Biodiversity Conservation Act 2016

4.1 Introduction

This section addresses the NSW Scientific Committee Final Determination (NSW Scientific Committee 2002) as well as a number of published guidelines and vegetation mapping reports that relate to *White Box Yellow Box Blakely's Red Gum Woodland* under the BC Act.

According to the guidelines for *Interpreting and identifying endangered ecological communities in the Sydney Basin* (DEC 2005) the information within the Final Determination and an assessment of the characteristic species is of paramount importance when determining if an endangered ecological community occurs on a site. In addition, the guidelines published by the NSW Scientific Committee (2010) state that the definition of an ecology community embodies the following three requirements:

- The constituents of a community must be species
- The species need to be brought together into an assemblage
- The assemblage of species must occupy a particular area

In addition, the NSW Scientific Committee (2010) states that the 'occurrence of one or two dominant species, of itself, is not evidence of the existence of an ecological community'. Instead the diagnosis of an ecological community requires an assessment of the overall species composition.

Section 4.2 provides a summary of broad-scale vegetation mapping and how it relates to the vegetation within the subject plots. **Section 4.3** addresses the Final Determination and **Section 4.4** provides an assessment of the characteristic species in the Final Determination in relation to the data collected in the subject plots and adjacent vegetation. The published guidelines and profiles only provide summaries and additional information to the Final Determination and are considered in the subsequent sections.

4.2 Vegetation mapping

4.2.1 Namoi CMA mapping

The vegetation of the Namoi catchment has been mapped at a broad scale by ELA (2009). The Regional Vegetation Communities (RVCs) that can or could potentially relate to *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) are shown in **Figure 6** and include:

- RVC 16. Box - gum grassy woodlands, New England Tablelands (<75%)
- RVC 17. Box - gum grassy woodlands, Brigalow Belt South and Nandewar (<75%)
- RVC 18. White Box grassy woodland, Brigalow Belt South and Nandewar (<75%)
- RVC 20. Rough-barked Apple - Blakely's Red Gum riparian grassy woodlands, Brigalow Belt South, Nandewar and New England Tablelands (5-25%)
- RVC 27. Derived grasslands, New England Tablelands (5-25%)
- RVC 28. Derived grasslands, Brigalow Belt South and Nandewar (5-25%)
- RVC 40. Stringybark - Blakely's Red Gum open forests, New England Tablelands (50-75%)
- RVC 96. Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South (25-50%)

ELA (2009) provides an EEC candidacy percentage score for each RVC and this is provided in brackets after each RVC in the list above. This score indicates the likelihood that a RVC would be identified as an EEC - contingent on more detailed site assessment.

It should be noted that only the mapped RVC 96. *Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South* corresponds to vegetation that is sampled by the subject plots. As shown above, the EEC candidacy is 25-50%. ELA (2009) note that this RVC has potential to be considered as *White Box Yellow Box Blakely's Red Gum Woodland* only if it contains 'grassy areas with abundant Blakely's Red Gum Woodland'.

Notwithstanding the above vegetation mapping and assessments of the potential of a RVC to be an EEC, it is considered that the determination of whether a site is *White Box Yellow Box Blakely's Red Gum Woodland* should be based on the assessment of the Final Determination with reference to data collected at the site-specific scale. In particular, this should include the assessment of the assemblage of characteristic species for that community, in accordance with DEC (2005). This assessment is provided in **Section 4.3** and **4.4**.

4.2.2 NSW Vegetation Classification and Assessment

Based on the surveys and analysis undertaken for this project, the vegetation sampled by the subject plots is considered to conform to the NSW Vegetation Classification and Assessment (VCA) ID No. 399 *Red gum – Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion* (Benson et al. 2010), which is mapped by ELA in the study area in **Figure 4**.

This VCA belongs to the Formation Group *Eucalyptus Communities of Inland Watercourses and Inner Floodplains* (Benson et al. 2010) and the Vegetation Class *Western Slopes Dry Sclerophyll Forests* of Keith (2004).

Benson et al. (2010) discusses the nature of grassy woodlands on medium to high nutrient soils in the NSW Brigalow Belt South, Nandewar and west New England Bioregions. These soils include high nutrient alluvial soils that range from brown to grey clay or loamy clay derived from fine-grained sedimentary or metamorphic substrates and black to brown loam to clay soils derived from volcanic substrates. However, VCA ID No. 399 is not part of this discussion and does not occur on such soils.

Instead, VCA ID No. 399 is discussed under the section entitled 'The forests of the Pilliga Scrub' where the most common tree is *Eucalyptus chloroclada* (Dirty Gum). VCA ID No. 399 is described as 'a riparian red gum – *Leptospermum polygalifolium* subsp. *transmontanum* (tea tree) woodland on the banks of the sandy streams throughout the Pilliga where other red gums *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus blakelyi* (Blakely's Red Gum) intergrade with it.

Table 9 of Benson et al. (2010) lists VCA ID No.'s that are considered to be part of EECs under the BC Act and EPBC Act. While some communities are listed as being part of *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act), VCA ID No. 399 is not listed. In addition, Benson et al. (2010) has given VCA ID No. 399 a threat code of LC (least concern).

VCA ID's that are known to occur in the Pilliga Forest that are considered to be part of the EEC (Benson et al. 2010) include:

- 421: Yellow Box – White Cypress Pine alluvial terrace flats grassy woodland in the Pilliga forests and surrounds, BBS Bioregion.
- 434: White Box grass shrub hill woodland on clay to loam soils on volcanic and sedimentary hills in the southern BBS Bioregion.

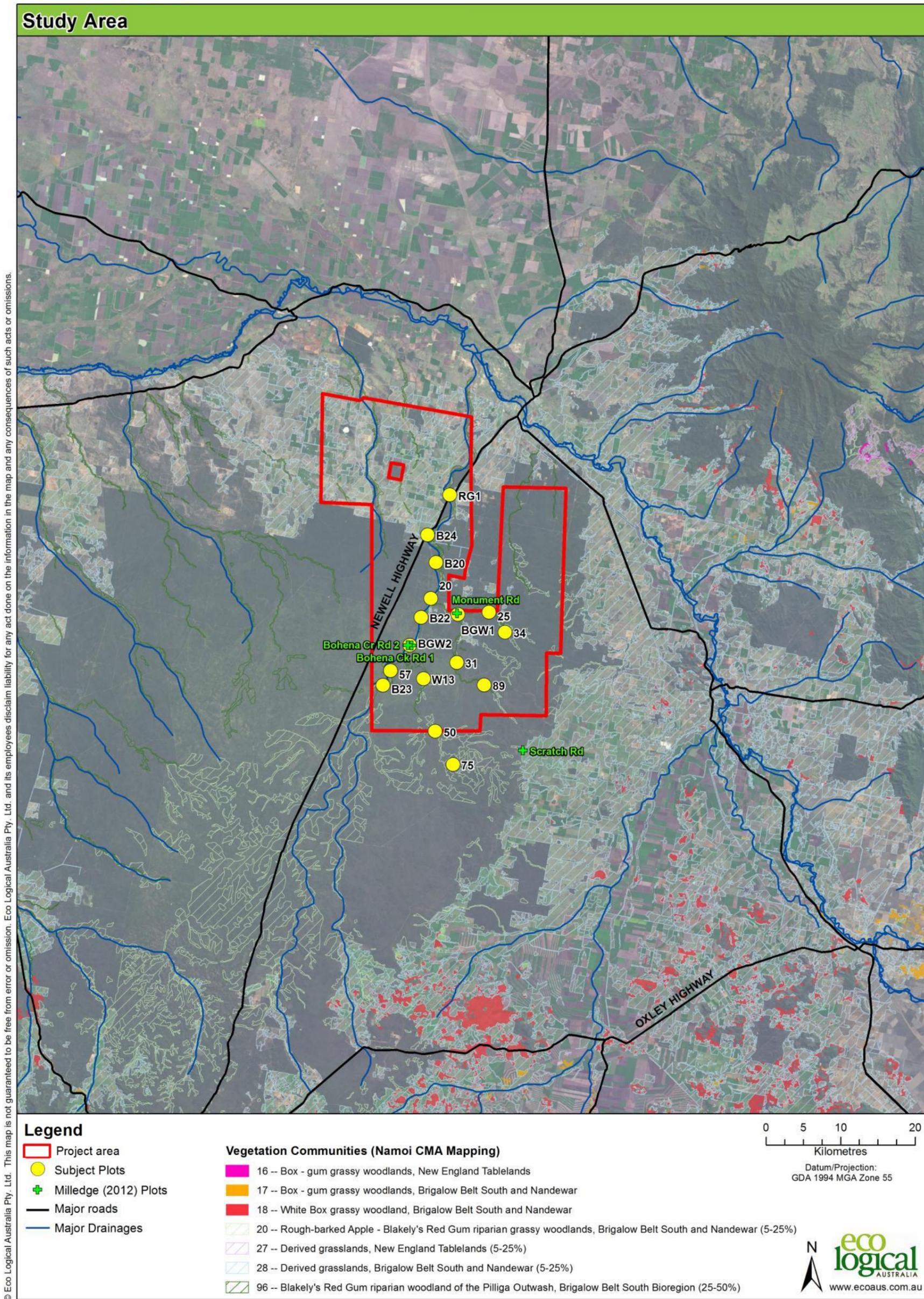


Figure 6: Study area

As noted above for the Namoi CMA mapping, the determination of whether a site is *White Box Yellow Box Blakely's Red Gum Woodland* (BC Act) should be based on an assessment of the Final Determination (**Section 4.3**), in particular the assessment of the assemblage of characteristic species for that community (**Section 4.4**).

4.3 Scientific Committee Final Determination

A comparison of the data collected in the field against each section in the Scientific Committee Final Determination (NSW Scientific Committee 2002) is provided in **Table 6**.

Table 6: Scientific Committee Final Determination

Scientific Committee determination	Assessment
<p>1. <i>White Box Yellow Box Blakely's Red Gum Woodland</i> is the name given to the ecological community characterised by the assemblage of species listed in paragraph 3. <i>White Box Yellow Box Blakely's Red Gum Woodland</i> is found on relatively fertile soils on the tablelands and western slopes of NSW and generally occurs between the 400 and 800 mm isohyets extending from the western slopes, at an altitude of c. 170m to c. 1200 m, on the northern tablelands (Beadle 1981). The community occurs within the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands and NSW South Western Slopes Bioregions.</p>	<p>See Section 4.4 for assessment of the assemblage of species that characterise this community. The assemblage of species recorded within the plots surveyed is not consistent with the final determination.</p> <p>'Relatively fertile' soils may be defined as those soils with moderate or higher inherent soil fertility. This ecological community is threatened due to its presence on 'relatively fertile' soils which have been largely cleared for agriculture on the tablelands and slopes of NSW.</p> <p>While the geological mapping for the study area (Figure 1) identifies that the plots surveyed occur across a range of geological units including silt, clay, sand and gravel, soil classification undertaken for this study has shown that the topsoil present in these areas is dominated by siliceous sand and loamy sands which are considered to be of low to moderately low soil fertility and as such are not considered to be 'relatively fertile'.</p> <p>The inherent soil fertility mapping undertaken by OEH (2013) supports this view with the plots surveyed occurring on areas of 'moderately low' fertility (Figure 3).</p> <p>The soil fertility within the plots surveyed is not consistent the final determination.</p> <p>Plots are located close to Narrabri which has a mean rainfall of 659 mm, which is within the 400 and 800 isohyets.</p> <p>The plots surveyed are located within the Brigalow Belt South Bioregion.</p>
<p>2. <i>White Box Yellow Box Blakely's Red Gum Woodland</i> includes those woodlands where the characteristic tree species include one or more of the following species in varying proportions and combinations - <i>Eucalyptus</i></p>	<p>All plots except for BGW 1 contained <i>Eucalyptus blakelyi</i> as a dominant or co-dominant species.</p>

Scientific Committee determination	Assessment
<p><i>albens</i> (White Box), <i>Eucalyptus melliodora</i> (Yellow Box) or <i>Eucalyptus blakelyi</i> (Blakely's Red Gum). Grass and herbaceous species generally characterise the ground layer. In some locations, the tree overstorey may be absent as a result of past clearing or thinning and at these locations only an understorey may be present. Shrubs are generally sparse or absent, though they may be locally common.</p>	<p><i>E. melliodora</i> and <i>E. albens</i> were not recorded in any subject plots, however both are known to occur in other areas of the Pilliga Forest.</p> <p>The ground layer generally has a very low cover and is characterised by grasses and herbs. However, smaller shrubs are often present.</p> <p>At some sites, particularly along the drainage line of Bohena Creek, the shrub layer is characterised by relatively thick clumps of the shrubs <i>Callistemon linearis</i> and <i>Leptospermum polygalifolium</i> subsp. <i>transmontanum</i>.</p> <p>See Section 4.4 for analysis of species.</p>
<p>3. White Box Yellow Box Blakely's Red Gum Woodland is characterised by the following assemblage of species:</p> <p>The total flora and fauna species list for the community is considerably larger than that given above, with many species present in only some sites or in very small quantity. In any particular site not all of the assemblage listed above may be present. At any one time, seeds of some species may only be present in the soil seed bank with no above-ground individuals present. The species composition of the site will be influenced by the size of the site, recent rainfall or drought conditions, its disturbance history and geographic and topographic location. The community is an important habitat for a diverse fauna (vertebrates and invertebrates), but detailed records are not available from most stands and the invertebrate fauna is poorly known.</p>	<p>See Section 4.4 for an analysis of characteristic species. See Appendix B in this report for the list of characteristic species.</p> <p>Surveys of subject plots have been undertaken over a number of years and seasons and over a relatively wide spatial range. This increases the chance that species with only seeds in the soil may have been detected across the whole dataset.</p> <p>However, at the site scale, seeds of some species may only have been present in the soil seed bank. The assessment of this likelihood is discussed in Section 4.4 and is based on species ecology, site characteristics such as soil type, fertility and microclimate conditions and vegetation data from adjoining areas.</p> <p>Most sites have been disturbed in the past by grazing and potential by altered fire regimes. Other potential site influences on species composition such as size, rainfall and location are discussed in Section 4.4.</p> <p>The plots surveyed are not consistent with this part of the final determination due to the absence of the characteristic assemblage of species in the understorey.</p>
<p>4. Woodlands with <i>Eucalyptus albens</i> are most common on the undulating country of the slopes region while <i>Eucalyptus blakelyi</i> and <i>Eucalyptus melliodora</i> predominate in grassy woodlands on the tablelands.</p> <p>Drier woodland areas dominated by <i>Eucalyptus albens</i> often form mosaics with areas dominated by <i>Eucalyptus blakelyi</i> and <i>Eucalyptus melliodora</i> occurring in more moist situations, while areas subject to waterlogging may be treeless.</p>	<p>The study area lies on the geographical boundary between the NSW western slopes and plains regions (Harden 1990).</p> <p>None of the subject plots contain <i>E. albens</i>. While most subject plots contain <i>E. blakelyi</i>, they are not located within the tablelands.</p> <p>Subject plots that contained <i>E. blakelyi</i> are located within and adjacent to ephemeral watercourses within the study area. However, they do not form a mosaic with any drier woodland areas dominated by <i>E. albens</i>.</p>

Scientific Committee determination	Assessment
<p><i>E. microcarpa</i> is often found in association with <i>E. melliodora</i> and <i>E. albens</i> on the south western slopes. Woodlands including <i>Eucalyptus crebra</i>, <i>Eucalyptus dawsonii</i> and <i>Eucalyptus moluccana</i> (and intergrades with <i>Eucalyptus albens</i>), for example in the Merriwa plateau, Goulburn River National Park and western Wollemi National Park, are also included. Intergrades between <i>Eucalyptus blakelyi</i> and <i>Eucalyptus tereticornis</i> may also occur here.</p>	<p>The surrounding woodland areas are dry woodlands dominated mostly by <i>E. chloroclada</i>, <i>E. pilligaensis</i>, <i>E. crebra</i>, <i>E. fibrosa</i> and <i>Corymbia trachyphloia</i>.</p> <p>No subject plots contained <i>E. moluccana</i> (or intergrades with <i>E. albens</i>), <i>E. dawsonii</i> or <i>E. melliodora</i>. The study area is not located in or near the Merriwa plateau, Goulburn River National Park or western Wollemi National Park.</p>
<p>5. Latitudinal and climatic gradients in the patterns of species present are found across the range of the community (eg. see Prober 1996 for variation in White Box). This is reflected in a gradual change in herb and grass species from northern to southern NSW (eg. Prober 1996). Within White Box Yellow Box Blakely's Red Gum Woodland, species such as <i>Rostellularia adscendens</i>, <i>Chloris ventricosa</i>, <i>Rytidosperma racemosa</i>, <i>Brunoniella australis</i>, <i>Cymbopogon refractus</i>, <i>Swainsona galegifolia</i>, <i>Notelaea microcarpa</i>, <i>Stackhousia viminea</i>, <i>Olearia elliptica</i>, <i>Jasminum suavissimum</i>, <i>Plantago gaudichaudii</i>, <i>Dichanthium sericeum</i>, <i>Plantago debilis</i> and <i>Wahlenbergia communis</i> are generally more restricted to more northern areas (eg. Prober 1996).</p> <p>Some other species in White Box Yellow Box Blakely's Red Gum Woodland were generally restricted to southern areas. These include <i>Gonocarpus elatus</i>, <i>Austrostipa blackii</i>, <i>Aristida behriana</i>, <i>Bracteantha viscosa</i>, <i>Rytidosperma auriculata</i> and <i>Austrostipa nodosa</i> (Prober 1996).</p>	<p>Of the species listed as being restricted to more northern areas the following were recorded within subject plots: <i>Cymbopogon refractus</i>, <i>Swainsona galegifolia</i> and <i>Wahlenbergia communis</i>. Other northern species located within the woodland surrounding the subject plots but which were not recorded in the plots include <i>Chloris ventricosa</i>, <i>Rytidosperma racemosa</i>, <i>Dichanthium sericeum</i> and <i>Plantago debilis</i>.</p> <p>None of the species generally restricted to southern areas were recorded in the subject plots or within the study area.</p> <p>This simply reflects the location of the study area next to the North Western Slopes rather than the South Western Slopes.</p>
<p>6. White Box Yellow Box Blakely's Red Gum Woodland includes vegetation described as <i>Eucalyptus albens</i> alliance and <i>E. melliodora</i> / <i>E. blakelyi</i> alliance in Beadle (1981), the <i>Eucalyptus albens</i> alliance in Moore (1953a,b), the grassy white box woodlands of Prober and Thiele (1993,1995) and Prober (1996) and the Grassy white box woodland of the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999. In the southern tablelands and parts of the southwest slopes, White Box Yellow Box Blakely's Red Gum Woodland are described in Thomas et al. (2000).</p>	<p>Beadle (1981) notes that '<i>Eucalyptus albens</i> occurs mostly on gently undulating country or on hills and the alliance often forms mosaics with the <i>E. melliodora</i> / <i>E. blakelyi</i> Alliance, which occupies flats, often along watercourses, whereas <i>E. albens</i> dominates the more elevated sites'. Soils are generally of relatively high fertility with the highest fertility derived from basalt and lowest from granite.</p> <p>The subject plots do not form mosaics with <i>E. albens</i> nor occur on relatively high fertility soils. Soils are sandy and derived from sedimentary rocks and alluvial sources. The subject plots do occur along ephemeral watercourses.</p> <p>Beadle (1981) states that the <i>E. melliodora</i> / <i>E. blakelyi</i> alliance is well defined (occurs between the 400 to 800 mm isohyets and at an altitude of approximately 170 to</p>

Scientific Committee determination	Assessment
	<p>1200 m on the Northern Tablelands). He notes that 'this alliances forms mosaics with the <i>E. albens</i> Alliance, the former occurring mainly on river flats, the latter on the adjacent undulating country'.</p> <p>The subject plots are not located on river flats that form a mosaic with the <i>E. albens</i> alliance. They also do not occur on elevated areas. The subject plots occur on siliceous sand to loamy sands. Adjacent vegetation is dominated by other species such as <i>Corymbia trachyphloia</i>, <i>E. chloroclada</i> and <i>E. crebra</i>.</p> <p>Moore (1953a,b) considers only the south-east Riverina area and does not describe vegetation within the Brigalow Belt South Bioregion. However, he does note that <i>E. albens</i> occurs further to the north up to Gunnedah and Inverell. <i>E. blakelyi</i> in this alliance is described as an associated tree which may become dominant with <i>E. melliodora</i> along 'non-permanent watercourses and more highly leached podsollic soils of the valleys'. <i>E. blakelyi</i> is also noted as an occasional species in the <i>E. albens</i> alliance and generally becomes more common from the top to the bottom of the slope.</p> <p><i>E. blakelyi</i> occurs in the <i>E. albens</i>–<i>E. melliodora</i>–<i>E. blakelyi</i> associated of the <i>E. albens</i> in Moore (1953a). It occurs in more favourable conditions where moisture retention is highest where water is received from run-off from higher areas.</p> <p>The subject plots are not located within deep valleys and do not intergrade within the <i>E. albens</i> alliance. Instead, they are located beside and within ephemeral watercourses in a low and flat landscape of relatively low fertility that falls outside of the areas discussed in Moore (1953a,b).</p> <p>Prober and Thiele (1993) describe the distribution and ecology of <i>E. blakelyi</i> following Moore (1953a,b).</p> <p>Discussing Grassy White Box Woodlands, Prober and Thiele (1995) and Prober (1996) state that 'White Box is 'usually the dominant tree in these woodlands, although other tree species (in particular, <i>E. melliodora</i> and <i>E. blakelyi</i> Maiden) can become locally dominant along non-permanent water courses or on deeper soils of valleys (Moore 1953a is cited).</p> <p>Prober and Thiele (1995) also indicate that 'White Box Woodland occurred on a variety of deep, relatively fertile soils derived from various parent materials,</p>

Scientific Committee determination	Assessment
	<p>including basalt, limestone, granite and various sedimentary and volcanic rocks’.</p> <p>The soils of the study area are largely derived from sandstone which is of low to moderately low fertility.</p> <p>Prober (1996) analyses woodland outside of the study area and is mainly concerned with the patterns in the species assemblage in the ground layer of Grassy White Box Woodlands and implications for reserve design.</p> <p>The references cited above concerning the Grassy White Box Woodlands describes <i>E. blakelyi</i> as an intergrade or as occurring in an association on valley flats or non-permanent watercourses within a mosaic of <i>E. albens</i>. The subject plots are not located within this position in the landscape and <i>E. blakelyi</i> is not associated with <i>E. albens</i> woodlands.</p>
<p>7. Related communities are the <i>Eucalyptus microcarpa</i>, <i>Eucalyptus pilligaensis</i> Grey Box/ <i>Eucalyptus populnea</i> Poplar Box communities of the western slopes and plains and the <i>Eucalyptus moluccana</i>, Grey Box, communities of the Clarence, lower Hunter Valley and Western Sydney. These are not covered by this Determination. Similarly the natural temperate grasslands and the <i>Eucalyptus pauciflora</i> grassy woodlands of the cooler parts of the southern tablelands are not covered by this Determination.</p>	<p>None of the vegetation communities sampled by the subject plots relate to the <i>Eucalyptus microcarpa</i>, <i>Eucalyptus pilligaensis</i> Grey Box / <i>Eucalyptus populnea</i> Poplar Box communities of the western slopes and plains.</p> <p>The study area is not in the Clarence, lower Hunter Valley, Western Sydney or the southern tablelands.</p>
<p>8. White Box Yellow Box Blakely's Red Gum Woodland has been drastically reduced in area and highly fragmented because of clearance for cropping and pasture improvement. Austin et al. (2000) found the community had been reduced to less than 1% of its pre-European extent in the Central Lachlan region. Comparable degrees of reduction have been documented for NSW south western slopes and southern Tablelands (estimated <4% remaining, Thomas et. al. 2000), and for the Holbrook area (estimated <7% remaining, Gibbons and Boak (2000). Gibbons and Boak (2000) found remnants of woodlands dominated by <i>Eucalyptus albens</i>, <i>E. melliodora</i> and <i>E. blakelyi</i> were severely fragmented. Further remnants of the community are degraded as a consequence of their disturbance history. Some remnants of these communities survive with the trees partly or wholly removed by post European activities, and conversely, often remnants of these communities survive with these tree species largely intact but with</p>	<p>The study area has been disturbed to varying degrees by fire, logging, grazing and weed invasion. However, the study area is part of a large expanse of native vegetation, and is not significantly fragmented by clearing.</p> <p>The soils within the vicinity of the subject plots are dominated by siliceous sand and loamy sands which are considered to be of low to moderately low soil fertility and as such are generally unsuitable for agriculture.</p> <p>The unsuitability of the soils within the study area for agriculture has resulted in the retention of vegetation in comparison to large areas of clearing on the tablelands and slopes of NSW.</p>

Scientific Committee determination	Assessment
<p><i>the shrub or ground layers degraded to varying degrees through grazing or pasture modification. Remnants are subject to varying degrees of threat that jeopardise their viability. These threats include: further clearing (for cropping, pasture improvement or other development); deterioration of remnant condition (caused by firewood cutting, increased livestock grazing, weed invasion, inappropriate fire regimes, soil disturbance and increased nutrient loads); degradation of the landscape in which remnants occur (including soil acidification, salinity, and loss of connectivity between remnants).</i></p>	
<p>9. <i>The understorey may be highly modified by grazing history and disturbance. A number of native species appear not to tolerate grazing by domestic stock and are confined to the least disturbed remnants (Dianella revoluta, Diuris dendrobioides, Microseris lanceolata, Pimelea curviflora, Templetonia stenophylla (Prober & Thiele 1995). Dominant pasture species typically change from Themeda australis, Austrostipa aristiglumis and Poa spp. to Austrostipa falcata, Rytidosperma spp. and Bothriochloa macra as grazing intensity increases (Moore 1953a). This may reflect differences in palatability of these species and their ability to tolerate grazing pressure. Light grazing and burning may also be a problem and lead to Aristida ramosa dominance (Lodge & Whalley 1989).</i></p>	<p>It is likely that understorey of the vegetation sampled by plots has been modified in the past by limited grazing as well as altered fire regimes. However, the vegetation sampled by the plots consisted of intact woodland and was no longer used for grazing.</p> <p>The only species recorded in the subject plots that appears to not tolerate grazing was <i>D. revoluta</i>. This species, along with <i>Templetonia stenophylla</i>, <i>Themeda australis</i> and <i>Bothriochloa</i> sp. were also recorded in other vegetation communities within the study area.</p> <p>The understorey was generally sparse with large areas of bare ground and dominant species frequently included <i>Aristida</i> sp., <i>Imperata cylindrica</i> and <i>Lomandra</i> spp. which are not typical of this ecological community. <i>Themeda australis</i> was not recorded in any of the subject plots, but has been observed as scattered individuals in the vicinity of the subject plots.</p> <p><i>Poa</i> spp. and <i>Austrostipa aristiglumis</i> have not been recorded in the study area. The subject plots were also not dominated by <i>A. falcata</i>, <i>Rytidosperma</i> spp. or <i>Bothriochloa</i> spp.</p> <p><i>A. ramosa</i> is a very widespread species and was recorded in a number of subject plots.</p> <p>The analysis of this EEC in Section 4.4 considers the description of the change in dominant species in woodland subject to grazing, as well as the assessment of the assemblage of species.</p>
<p>10. <i>The condition of remnants ranges from relatively good to highly degraded, such as paddock remnants with weedy understories and only a few hardy natives left. A number of less degraded remnants have survived in Travelling Stock Routes, cemeteries and reserves, although because of past and present</i></p>	<p>The subject plots were located in areas that are likely to have been grazed lightly in the past and that have been subject to altered fire regimes. Some sites contained weedy species, probably as a result of past and recent disturbances, including intermittent high flows.</p>

Scientific Committee determination	Assessment
<p><i>management practices understorey species composition may differ between the two land uses. Some remnants of the community may consist of only an intact overstorey or an intact understorey, but may still have high conservation value due to the flora and fauna they support. Other sites may be important faunal habitat, have significant occurrences of particular species, form part of corridors or have the potential for recovery. The conservation value of remnants may be independent of remnant size.</i></p>	<p>It is also likely that the propagules of some weed species would have arrived on via wind or carried by mammals and birds.</p> <p>No sites were located in Travelling Stock Routes, cemeteries or reserves.</p>
<p><i>11. Disturbed remnants are still considered to form part of the community including remnants where the vegetation, either understorey, overstorey or both, would, under appropriate management, respond to assisted natural regeneration, such as where the natural soil and associated seed bank are still at least partially intact.</i></p>	<p>Noted. All of the vegetation within the plots in this analysis contained a ground, shrub and tree layer.</p>
<p><i>12. The community is poorly represented in conservation reserves. There are small occurrences of White Box Yellow Box Blakely's Red Gum Woodland in Border Ranges National Park, Goobang National Park, Goulburn River National Park, Manobalai Nature Reserve, Mt Kaputar National Park, Oxley Wild Rivers National Park, Queanbeyan Nature Reserve, Towari National Park, Warrumbungle National Park, Wingen Maid Nature Reserve and Wollemi National Park. The community also occurs in the following State Conservation Areas, Copeton State Conservation Area, Lake Glenbawn State Conservation Area and Lake Keepit State Conservation Area.</i></p>	<p>Mt Kaputar National Park is located approximately 25 km to the north-west and Warrumbungle National Park is located approximately 66 km to the south-west of the study area.</p> <p>Both of these National Parks include geological formations (including volcanics) from which relatively 'fertile soils' are derived.</p>
<p><i>13. Fauna species of conservation significance found in some stands of White Box Yellow Box Blakely's Red Gum Woodland include,</i></p> <ul style="list-style-type: none"> • <i>Aprasia parapulchella - Pink-tailed Legless Lizard</i> • <i>Burhinus grallarius - Bush Stone-curlew</i> • <i>Cacatua leadbeateri - Major Mitchell's Cockatoo</i> • <i>Climacteris picumnus victoriae - Brown Treecreeper</i> • <i>Dasyurus maculatus - Spotted-tailed Quoll</i> • <i>Delma impar - Striped Legless Lizard</i> • <i>Grantiella picta - Painted Honeyeater</i> 	<p>Noted. Not related to the analysis.</p> <p>None of these fauna species are restricted to <i>White Box Yellow Box Blakely's Red Gum Woodland</i>. Of these, the following have been recorded within the study area across a number of different vegetation communities and landscapes:</p> <ul style="list-style-type: none"> • <i>Grantiella picta - Painted Honeyeater</i> • <i>Hoplocephalus bitorquatus - Pale-headed Snake</i> • <i>Lophoictinia isura - Square-tailed Kite</i> • <i>Melanodryas cucullata cucullata - Hooded Robin</i> • <i>Neophema pulchella - Turquoise Parrot</i>

Scientific Committee determination	Assessment
<ul style="list-style-type: none"> • <i>Hoplocephalus bitorquatus</i> - Pale-headed Snake • <i>Lathamus discolor</i> - Swift Parrot • <i>Lophoictinia isura</i> - Square-tailed Kite • <i>Melanodryas cucullata cucullata</i> - Hooded Robin • <i>Melithreptus gularis gularis</i> - Black-chinned Honeyeater • <i>Neophema pulchella</i> - Turquoise Parrot • <i>Ninox connivens</i> - Barking Owl • <i>Petaurus norfolcensis</i> - Squirrel Glider • <i>Phascolarctos cinereus</i> - Koala • <i>Polytelis swainsonii</i> - Superb Parrot • <i>Pomatostomus temporalis temporalis</i> - Grey-crowned Babbler • <i>Pyrrholaemus sagittata</i> - Speckled Warbler • <i>Saccolaimus flaviventris</i> - Yellow-bellied Sheathtail-bat • <i>Stagonopleura guttata</i> - Diamond Firetail • <i>Synemon plana</i> - Golden Sun Moth • <i>Tyto novaehollandiae</i> - Masked Owl • <i>Varanus rosenbergi</i> - Rosenberg's Goanna • <i>Xanthomyza phrygia</i> - Regent Honeyeater 	<ul style="list-style-type: none"> • <i>Ninox connivens</i> - Barking Owl • <i>Petaurus norfolcensis</i> - Squirrel Glider • <i>Phascolarctos cinereus</i> - Koala • <i>Pomatostomus temporalis temporalis</i> - Grey-crowned Babbler • <i>Pyrrholaemus sagittata</i> - Speckled Warbler • <i>Saccolaimus flaviventris</i> - Yellow-bellied Sheathtail-bat • <i>Stagonopleura guttata</i> - Diamond Firetail • <i>Tyto novaehollandiae</i> - Masked Owl <p>None of these flora species are restricted to <i>White Box Yellow Box Blakely's Red Gum Woodland</i>. Of these, the following have been recorded within the study area across a number of different vegetation communities and landscapes:</p> <ul style="list-style-type: none"> • <i>Diuris</i> spp. • <i>Pterostylis</i> spp. • <i>Swainsona</i> spp. <p>Of these key threatening processes the following are likely to occur within the vegetation sampled by the plots:</p> <ul style="list-style-type: none"> • Predation by the European Red Fox <i>Vulpes vulpes</i>. • Predation by the Feral Cat, <i>Felis catus</i>.
<p>A number of plant species of conservation significance are likely to occur in <i>White Box Yellow Box Blakely's Red Gum Woodland</i></p>	
<ul style="list-style-type: none"> • <i>Ammobium craspedioides</i> • <i>Bothriochloa biloba</i> • <i>Dichanthium setosum</i> • <i>Discaria pubescens</i> • <i>Diuris</i> spp. • <i>Prasophyllum petilum</i> • <i>Pterostylis</i> spp. • <i>Rutidosia leptorrhynchoides</i> • <i>Swainsona</i> spp. 	
<p>A number of key threatening processes also occur in <i>White Box Yellow Box Blakely's Red Gum Woodland</i>. These include: <i>Clearing of native vegetation, Predation by the European Red Fox Vulpes vulpes, Predation by the Feral Cat, Felis catus.</i></p>	

Scientific Committee determination	Assessment
<p>14. In view of the small size of existing remnants, and the threat of further clearing, disturbance and degradation, the Scientific Committee is of the opinion that White Box Yellow Box Blakely's Red Gum Woodland is likely to become extinct in nature in New South Wales unless the circumstances and factors threatening its survival or evolutionary development cease to operate and that listing as an endangered ecological community is warranted.</p>	<p>Noted. Not related to the analysis.</p>

In conclusion, based on the low to moderately low soil fertility and the absence of the characteristic assemblage of species in the understorey, the vegetation present in the subject plots is not considered to be the EEC *White Box Yellow Box Blakely's Red Gum Woodland*.

4.4 Characteristic species analysis

This section presents the results of an analysis of the subject plots in relation to the list of characteristic species in the Final Determination. The list of characteristic species, their habitat, distribution and the plots in which they were recorded is provided in **Appendix B**. A list of characteristic species that were recorded in subject plots is also provided in **Table 8**.

As noted by DEC (2005), the list of characteristic species is 'paramount to determining which endangered ecological community is present'. This list includes those species most commonly found in those communities, however, they can also be found in other communities (DEC 2005). DEC (2005) also states that the difference between other communities and the endangered ecological community in question is based on the 'combinations of those species (including cover and abundance) rather than the species' strict presence or absence'.

This analysis of the species assemblage in the diagnosis of this EEC also takes into account guidelines published by the NSW Scientific Committee (2010) which state that the definition of an ecological community embodies the following three requirements:

- The constituents of a community must be species.
- The species need to be brought together into an assemblage.
- The assemblage of species must occupy a particular area.

It should be noted that although surveys for the subject plots have been undertaken under a range of seasonal conditions over more than four years it is still possible that some species were not detected and still have potential to occur. However, it is likely that data collected provides a robust description of the vegetation, particularly the dominant ground layer species. Many plots were sampled during January 2011 in a relatively good season which resulted in the detection of many annual species that respond to rainfall.

4.4.1 Overall plot data

The subject plots included 16 of the 327 plots sampled for the Narrabri Gas Project over more than four years. The subject plots were located within areas that were either dominated or co-dominated by *E. blakelyi* or had been identified by Milledge (2012) as *White Box Yellow Box Blakely's Red Gum Woodland*. **Table 7** compares the species recorded in the plots with the list of characteristic species in the Final

Determination. Where *Aristida*, *Austrostipa*, *Bothriochloa* and *Swainsona* species were recorded to only species level in a plot, a precautionary approach was adopted, and if a characteristic species of that genus had not been already been recorded in that plot, then they were treated as if they were a characteristic species for that plot.

Table 7: Plot data percentages

Plot number	Species	Exotic species	Native species	Number of characteristic species	% of native species within the plot that are characteristic species	% of characteristic species within the plot from the final determination
January 2011						
57	37	13	24	7	29.2	7.4
75	19	0	19	6	31.6	6.3
89	22	0	22	8	36.4	8.4
50	48	1	47	10	21.3	11.2
20	17	5	12	5	41.7	5.3
25	15	0	15	5	33.3	5.3
31	16	0	16	6	37.5	6.3
34	20	0	20	9	45.0	9.5
October 2013						
BGW 1	34	0	34	11	32.4	11.2
BGW 2	34	11	23	7	30.4	7.4
W13	22	0	22	5	22.7	5.3
November 2013						
BG1	31	8	23	8	34.8	8.4
B24	22	6	16	4	25.0	4.2
B23	25	7	18	7	38.9	7.4
B22	27	11	16	4	25.0	4.2
B20	37	10	27	9	33.3	9.5

The number of native species within the subject plots ranged from 12 in plot 20 to 47 in plot 50. In some plots there were no exotic species while in others the exotic species comprised over 40% of the total number of species present. The number of exotic species is not relevant to the analysis of *White Box Yellow Box Blakely's Red Gum Woodland* because sites can be of a degraded nature (and hence support exotic species) yet still be the ecological community.

The total number of characteristic species within the subject plots ranged from four in plots B22 and B24 to 11 in plot BGW 1. The percentage of the total number of native species within the subject plots that

were characteristic species ranged from 21.3% in plot 50 to 45% in plot 34. The percentage of the total number of characteristic species (95 in total) in the Final Determination that occurred within the plots ranged from 4.2% in plots B24 and B22 to 11.2% in plots 50 and BGW 1.

4.4.2 Percentage of characteristic species from the Final Determination

Plot BGW 1 contained 11 of the 98 characteristic species listed in the Final Determination, which is 11.2%, and is one of the plots with highest percentage of characteristic species. The mid-storey species was *Callitris glaucophylla* (characteristic species) and the dominant ground layer species were *Lomandra longifolia* (cover of 25-50%) and *Arundinella nepalensis* (cover of 5-25%), neither of which are characteristic species. The cover/abundance of the characteristic species in plot BGW 1 was:

- *Aristida ramosa* <5%, few
- *Bothriochloa* sp. <5%, solitary
- *Callitris glaucophylla* <5% numerous
- *Cheilanthes sieberi* <5%, few
- *Chrysocephalum apiculatum* <5%, few
- *Cymbopogon refractus* <5%, few
- *Dianella revoluta* <5%, solitary
- *Glycine clandestina* <5%, solitary
- *Lissanthe strigosa* <5%, solitary
- *Melichrus urceolatus* <5%, few
- *Wahlenbergia communis* <5%, few

The eleven characteristic species have very low cover/abundance values in this plot. Other non-characteristic species also have very low cover/abundance values in this plot and this reflects the sparse nature of this type of woodland vegetation in the study area – most species have low cover/abundance and generally only the one or two dominant species have a higher cover/abundance. The dominant species in the mid and ground layers (those with a high cover/abundance) are not characteristic species and the majority of species (67.6%) are not characteristic species.

Table 8 contains a list of characteristic species that have been recorded in both the subject plots and in other plots surveyed by ELA in the study area and the surrounding woodland for the Narrabri Gas Project. A total of 24 (25.3%) characteristic species were recorded in the subject plots. A total of 24 (25.3%) characteristic species were recorded in plots in other areas that are not *White Box Yellow Box Blakely's Red Gum Woodland* due to the dominant tree species and/or a dense (>30%) shrubby layer. Together, a total of total of 43 (45.3%) characteristic species have been recorded in the plots surveyed for the Narrabri Gas Project.

Table 8: Characteristic species analysis

Characteristic species	Subject plots	Recorded in other vegetation communities
<i>Acacia buxifolia</i>		x
<i>Acacia implexa</i>		
<i>Acacia paradoxa</i>		
<i>Allocasuarina verticillata</i>		
<i>Alectryon oleifolius</i>		
<i>Aristida behriana</i>		

Characteristic species	Subject plots	Recorded in other vegetation communities
<i>Aristida ramosa</i>	x	x
<i>Asperula conferta</i>		x
<i>Atalaya hemiglauca</i>		
<i>Rytidosperma auriculata</i>		
<i>Rytidosperma bipartita</i>		x
<i>Rytidosperma racemosa</i>		x
<i>Rytidosperma richardsonii</i>		
<i>Austrostipa aristiglumis</i>		
<i>Austrostipa blackii</i>		
<i>Austrostipa nodosa</i>		
<i>Austrostipa scabra</i>	x	x
<i>Bothriochloa macra</i>	x	x
<i>Brachychiton populneus</i>	x	x
<i>Brachyloma daphnoides</i>	x	x
<i>Bracteantha viscosa</i>		
<i>Brunoniella australis</i>		x
<i>Bulbine bulbosa</i>		
<i>Bursaria spinosa</i>		
<i>Callitris endlicheri</i>	x	x
<i>Callitris glaucophylla</i>	x	x
<i>Capparis mitchellii</i>		
<i>Cassinia longifolia</i>		
<i>Cassinia quinquefaria</i>		
<i>Cheilanthes sieberi</i>	x	x
<i>Chloris truncata</i>		x
<i>Chloris ventricosa</i>		x
<i>Chrysocephalum apiculatum</i>	x	x
<i>Cymbopogon refractus</i>	x	x
<i>Dianella longifolia</i>	x	x
<i>Dianella revoluta</i>	x	x
<i>Dichanthium sericeum</i>		x
<i>Dichelachne micrantha</i>		x

Characteristic species	Subject plots	Recorded in other vegetation communities
<i>Dichelachne rara</i> [syn. <i>Dichelachne sciurea</i>]		
<i>Diuris dendrobioides</i>		
<i>Dodonaea viscosa</i>	x	x
<i>Echinopogon caespitosus</i>	x	
<i>Ehretia membranifolia</i>		
<i>Elymus scaber</i>		
<i>Eremophila mitchellii</i>		
<i>Eucalyptus blakelyi</i>	x	x
<i>Eucalyptus albens</i>		x
<i>Eucalyptus bridgesiana</i>		
<i>Eucalyptus conica</i>	x	x
<i>Eucalyptus goniocalyx</i>		
<i>Eucalyptus melliodora</i>		
<i>Eucalyptus microcarpa</i>		
<i>Eucalyptus nortonii</i>		
<i>Eulalia aurea</i>		x
<i>Exocarpos cupressiformis</i>		x
<i>Geijera parviflora</i>		x
<i>Geranium solanderi</i>		
<i>Glycine clandestine</i>	x	x
<i>Glycine tabacina</i>		x
<i>Glycine tomentella</i>		
<i>Gonocarpus elatus</i>		
<i>Goodenia pinnatifida</i>		
<i>Hibbertia linearis</i>		
<i>Hibbertia obtusifolia</i>	x	x
<i>Hypericum gramineum</i>		x
<i>Jacksonia scoparia</i>		
<i>Jasminum lineare</i>		x
<i>Jasminum suavisimum</i>		x
<i>Leptorhynchos squamatus</i>		
<i>Lissanthe strigosa</i>	x	x

Characteristic species	Subject plots	Recorded in other vegetation communities
<i>Lomandra filiformis</i>		x
<i>Melichrus urceolatus</i>	x	x
<i>Microseris lanceolata</i>		
<i>Notelaea microcarpa</i>		
<i>Olearia elliptica</i>		
<i>Olearia viscidula</i>		
<i>Oxalis perennans</i>	x	x
<i>Pandorea pandorana</i>		
<i>Panicum queenslandicum</i>		
<i>Parsonsia eucalyptophylla</i>		x
<i>Pimelea curviflora</i>		
<i>Plantago debilis</i>		x
<i>Plantago gaudichaudii</i>		
<i>Poa labillardieri</i>		
<i>Poa sieberiana</i>		
<i>Rostellularia adscendens</i>		
<i>Rumex brownii</i>	x	x
<i>Sida corrugata</i>		
<i>Sorghum leiocladum</i>		
<i>Stackhousia monogyna</i>		
<i>Stackhousia viminea</i>		
<i>Swainsona galegifolia</i>	x	x
<i>Templetonia stenophylla</i>		x
<i>Themeda australis</i>		x
<i>Wahlenbergia communis</i>	x	x
Total	24	43

It is possible that some characteristic species that were recorded only in other vegetation communities could occur in the vegetation sampled by the subject plots, but were not recorded due to factors such as disturbance/season/presence in the seed bank. For example, *Oxalis perennans* is a widespread small herb that flowers from May to December. It was recorded only in plot 57 but was recorded in 27 other plots for the Narrabri Gas Project. A possible reason for the fact that it wasn't recorded in most of subject plots is that it was not flowering or the above ground vegetation had died off. Another possible reason

for not detecting it in the subject plots is that the habitat (most commonly loamy sands) was not suitable for it, since it commonly occurs on heavy-textured soils (Conn 1992).

Notwithstanding the above, the sampling of the subject plots over a number of different seasons, conditions and wide spatial and disturbance scales, and the fact that majority of these species are perennials, suggests that the likelihood of recording these characteristic species in the subject plots would have been relatively high if they occurred in high frequencies. These species were recorded more frequently in other plots and are usually widespread over their range. Consequently, the lack of their detection in 16 subject plots, which were spread over a relatively wide area, suggests that if they were present in VCA ID No. 399, they would be likely to occur only in low frequencies.

Soils within the subject plots ranged from unconsolidated sand over loamy sand to fine textured light brown loamy sand. These soil types would be considered to be a very low fertility level compared to soils in the Brigalow Belt Bioregion where *White Box Yellow Box Blakely's Red Gum Woodland* is known to occur. The following characteristic species were not recorded in the subject plots, but were recorded in a relatively small number of other plots and are usually more common on slightly heavier soils:

- *Rytidosperma bipartita* (1 plot)
- *Chloris truncata* (4 plots)
- *C. ventricosa* (1 plot)
- *Dichanthium sericeum* (3 plots)
- *Plantago debilis* (3 plots)

The absence or low abundance of some characteristic species across the 129 plots surveyed supports the theory that soils in the subject plots are of relatively low fertility compared to the wider region. Consequently, it is expected that if any characteristic species that commonly occur on fertile soils actually do occur in the riparian woodland then they would be likely to occur at relatively low frequencies due to low habitat suitability.

The species with the highest frequency across all the subject plots (i.e. those that were recorded in over half of the subject plots) were:

- *Eucalyptus blakelyi* (characteristic species) (14 plots)
- *Gahnia aspera* (11 plots)
- *Lomandra longifolia* (11 plots)
- *Acacia deanei* subsp. *deanei* (10 plots)
- *Cymbopogon refractus* (characteristic species) (9 plots)

E. blakelyi is a typical tree species that occurs in riparian vegetation, which is also consistent with the description of the vegetation of VCA ID No. 399 in Benson et al. (2010). The other more frequently occurring species include two sedges and a wattle which are not characteristic species, which is also consistent with VCA ID No. 399. *C. refractus* occurs at a high frequency, however this species is widespread. This combination of high frequency species is considered to be typical of VCA ID No. 399. The low frequency of characteristic species from the Final Determination in the subject plots, along with the high frequency of species that are typical of VCA ID No. 399, suggests that the species assemblage in this vegetation is not characteristic of *White Box Yellow Box Blakely's Red Gum Woodland*.

Taking the above discussion into account it is clear that the majority of characteristic species listed in the Final Determination are not present or would only occur in very low frequencies in the *E. blakelyi* riparian woodland vegetation (VCA ID No. 399) sampled by the subject plots. In particular, characteristic species which are usually more common on higher fertility soils are either absent or in very low frequencies in the

subject plots. Other characteristic species recorded in surveys for the Narrabri Gas Project occur in higher frequencies in adjacent vegetation communities that are not *White Box Yellow Box Blakely's Red Gum Woodland*.

In conclusion, based on the analysis of the percentage of characteristic species from the Final Determination that are present in the subject plots, it is concluded that vegetation sampled by the subject plots is not consistent with the Final Determination for *White Box Yellow Box Blakely's Red Gum Woodland* because the assemblage of species that characterise this *E. blakelyi* riparian woodland (VCA ID No. 399):

- Is dominated by species that are not characteristic species listed in the Final Determination, are widespread and more suited to low fertility coarse-grained sandy habitats (compared with relatively higher fertility habitats).
- Includes only a low percentage of characteristic species listed in the Final Determination.
- Includes of a very low frequency of characteristic species that are more common on higher fertility soils.
- Includes characteristic species from the Final Determination that mostly have only low cover/abundance values.
- Does not include additional characteristic species from the Final Determination that were found in the surrounding vegetation communities.

4.4.3 Percentage of native species that are characteristic species from the Final Determination

Some subject plots have a relatively high percentage of native species that are characteristic species. This is the case for plots 34, 20 and B23, in which the percentage of native species in the plot that are characteristic species is above 40% (**Table 7**). Dominant species and characteristic species for these plots are shown in **Table 9**.

Table 9: Plots with relatively higher percentages of native species that are characteristic species

Plot Number	Dominant canopy species	Dominant mid-storey species	Dominant ground layer species	Characteristic species present in plot
34	<i>Angophora floribunda</i> <i>Eucalyptus blakelyi</i>	<i>Cassinia arcuata</i> <i>Brachyloma daphnoides</i> <i>Hibbertia</i> sp.	<i>Pomax umbellata</i> <i>Lomandra longifolia</i> <i>Cymbopogon refractus</i>	<i>Brachyloma daphnoides</i> <i>Callitris glaucophylla</i> <i>Cheilanthes sieberi</i> <i>Cymbopogon refractus</i> <i>Dianella revoluta</i> <i>Eucalyptus blakelyi</i> <i>Glycine clandestina</i> <i>Melichrus urceolatus</i> <i>Wahlenbergia</i> sp.
20	<i>Eucalyptus blakelyi</i> <i>Callitris glaucophylla</i>	<i>Acacia</i> sp.	<i>Bidens subalternans</i> * <i>Austrostipa verticillata</i>	<i>Callitris glaucophylla</i> <i>Cheilanthes. sieberi</i> <i>Eucalyptus blakelyi</i> <i>Glycine clandestina</i> <i>Rumex brownii</i>

Plot Number	Dominant canopy species	Dominant mid-storey species	Dominant ground layer species	Characteristic species present in plot
B23	<i>Angophora floribunda</i> <i>Eucalyptus blakelyi</i>	<i>Acacia deanei</i> subsp. <i>deanei</i>	<i>Lomandra longifolia</i> <i>Verbena tenuisecta</i> * <i>Austrostipa scabra</i> subsp. <i>scabra</i> <i>Cynodon dactylon</i>	<i>Austrostipa. scabra</i> subsp. <i>scabra</i> <i>Callitris endlicheri</i> <i>Chrysocephalum apiculatum</i> <i>Eucalyptus blakelyi</i> <i>Glycine</i> sp. <i>Wahlenbergia</i> sp.

Species in bold type are characteristic species, * indicates exotic species

Since the dominance of any species in a community can change over time as a result of conditions and disturbance regimes that affect germination, establishment, seed set and growth, the occurrence of 'one or two dominant species, of itself, is not evidence of the existence of an ecological community' (NSW Scientific Committee 2010). However, the guidelines for *Interpreting and identifying endangered ecological communities in the Sydney Basin* (DEC 2005) indicate that communities are 'differentiated by the combination of those species (including cover and abundance) rather than the species' strict presence or absence'. Therefore, discussion of dominant species (i.e. those with a high cover/abundance) needs to take into account more than just one or two dominant species as well as the proportion and cover/abundance of other species, including characteristic species.

In plot 34 there are nine characteristic species in total. One characteristic species is present as a dominant species in each structural layer (along with other, non-characteristic species). The presence of only three characteristic species as part of the dominant species in the plot is not evidence that this vegetation is *White Box Yellow Box Blakely's Red Gum Woodland*.

As noted above, identification of an ecological community should also take into account the total species assemblage. As noted in **Section 4.4.2**, it is unlikely that a high number of characteristic species would occur in the vegetation sampled by the subject plots in any high frequencies. In plot 34, the relatively high proportion of characteristic species (45%) is not of itself typical of the species assemblage of *White Box Yellow Box Blakely's Red Gum Woodland*. This is because there is a low percentage of the total characteristic species present (9.5%), the total species diversity is low, and the majority of the characteristic species present have low cover/abundance values.

In plot 20 there are five characteristic species in total. Only two are dominant species in the canopy layer. This is fairly typical of riparian vegetation along the larger creeks such as Bohena Creek in the study area. This is due to the low percentage of the total characteristic species (9.5%), the low species diversity, and the fact that the other more common characteristic species have low cover/abundance values.

In plot B23 there are seven characteristic species in total. Of the two dominant canopy species only *E. blakelyi* is a characteristic species. Of the four dominant ground layer species only *A. scabra* subsp. *scabra* is a dominant species, which has a very widespread distribution (see **Appendix B**). As for the two plots discussed above (plot 34 and 20), the relatively high proportion of characteristic species (38.9%) present does not automatically qualify the species assemblage as *White Box Yellow Box Blakely's Red Gum Woodland* due to the low percentage of the total characteristic species (7.4%), the low species diversity, and the fact that the other more common characteristic species have low cover/abundance values.

It is concluded that vegetation sampled by the subject plots with a relatively high percentage of characteristic species as a proportion of the total species present in the subject plots is not consistent with the Final Determination for *White Box Yellow Box Blakely's Red Gum Woodland* because:

- The relatively high percentage of native species that are characteristic species is actually due to the lower total number of native species in these plots.
- The number of characteristic species listed in the Final Determination in plots as a percentage of the total number of native species present is actually a very low percentage of characteristic species listed in the Final Determination.
- The majority of the dominant species within the structural layers in these plots are not characteristic species.
- Most of the characteristic species recorded in the plots have low cover/abundance values in these plots.

4.5 Profiles, fact sheets and guidelines

This section provides a brief assessment of relevant profiles, fact sheets and guidelines produced for *White Box Yellow Box Blakely's Red Gum Woodland*. These documents are provided as additional tools, however caution is required as the legal definition of the EEC is contained within the Final Determination (**Section 4.3**).

4.5.1 Office of Environment and Heritage profile

The online profile for *White Box Yellow Box Blakely's Red Gum Woodland* provides a description, notes on distribution, habitat and ecology, threats, recovery strategies and 'activities to assist this species' and information sources (Office of Environment and Heritage (OEH) 2017).

The brief description and notes on habitat and ecology provided is a summary from the Final Determination. However, it does state that remnants generally occur on fertile lower parts of the landscape where resources such as water and nutrients are abundant. This is not consistent with the vegetation sampled by the subject plots since these riparian zones are ephemeral and the soil is sandy and of low to moderately low fertility.

4.5.2 Fact sheet

The undated fact-sheet provided by NSW National Parks and Wildlife Service (NPWS) (Undated(a)) refers to the Final Determination and the 'Identification guidelines for Endangered Ecological Communities: White Box-Yellow Box-Blakely's Red Gum Woodlands (Box-Gum Woodland)'.

It also contains general advice on identifying Box-Gum Woodlands (*White Box Yellow Box Blakely's Red Gum Woodland*) relating to the presence or prior presence of *E. albens*, *E. melliodora* and/or *E. blakelyi* and the nature of the understorey and ground layer. These factors have been discussed in **Section 4.4** above and the identification guidelines are addressed in the following sections (**Section 4.5**).

4.5.3 Identification guidelines

These identification guidelines (NPWS undated (b)) provide information to assist in the identification of *White Box Yellow Box Blakely's Red Gum Woodland* and also refer to the Final Determination of this community.

These guidelines state that there are five main features in the Final Determination that govern whether the EEC (endangered ecological community) exists at a site and these are addressed below:

1. *Whether the site is within the area defined in the Determination.*

The subject plots are located within the Brigalow Belt South Bioregion.

2 Whether the characteristic trees of the site are (or are likely to have been) White Box, Yellow Box or Blakely's Red Gum.

The characteristic trees of the subject plots include Blakely's Red Gum.

3. Whether the site is mainly grassy.

The subject plots are generally sparse with grasses and patches of shrubs.

4. Whether any of the listed characteristic species occur (including as part of the seedbank in the soil).

This is discussed in **Section 4.4**. Characteristic species are present within the subject plots.

5. If the site is degraded, whether there is potential for assisted natural regeneration of the overstorey or understorey.

Some of the subject plots have probably been degraded in the past due to grazing, changes to fire regimes, logging and soil disturbance. However, they are relatively intact. The guidelines also discuss how the poor conditions of a site do not preclude the site from being the EEC. This is not relevant to the subject plots.

The guidelines provide a key for use to determine whether Box-Gum woodlands exist on a site. This is provided below with the relevant choices for the subject plots highlighted by underlining.

1 The site is in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands or NSW South Western Slopes Bioregions: 2

1* The site is outside the above bioregions: the site is not Box-Gum Woodland

2 There are no native species in the understorey, and the site is unlikely to respond to assisted natural regeneration (see section on Degraded Sites, page 3): the site is not Box-Gum Woodland

2* The understorey is otherwise: 3

3 The site has trees: 4

3* The site is treeless, but is likely to have supported White Box, Yellow Box or Blakely's Red Gum prior to clearing: 5

4 White Box, Yellow Box or Blakely's Red Gum, or a combination of these species, are or were present: 5

4* White Box, Yellow Box or Blakely's Red Gum have never been present: the site is not Box-Gum Woodland

5 The site is predominantly grassy: the site is Box-Gum Woodland

5* The understorey of the site is dominated by shrubs excluding pioneer species (see section on The Understorey: page 2): the site is not Box-Gum Woodland

While following this key would indicate that most of the subject plots would be *White Box Yellow Box Blakely's Red Gum Woodland*, it is considered that this key is inconsistent with the principles outlined by

the NSW Scientific Committee (2010) which specifies that an ecology community embodies the following three requirements:

- The constituents of a community must be species
- The species need to be brought together into an assemblage
- The assemblage of species must occupy a particular area (usually a bioregion)

For example, when considering step 5 in the key it could be the case that the grasses that dominate a site are not listed characteristic grasses and that there is also a low percentage of characteristic species present (which is the case for some of the subject plots). As noted in the NSW Scientific Committee (2010) the list of assemblage of species is paramount to determining which endangered ecological community is present and such sites would not be likely to be considered to be *White Box Yellow Box Blakely's Red Gum Woodland* according to an assessment based on the Final Determination.

Therefore, for the purposes of determining whether the subject plots are *White Box Yellow Box Blakely's Red Gum Woodland* or not, this key is not considered adequate for differentiating between areas of the community based on floristics.

4.5.4 Field identification guidelines

The Department of Environment and Climate Change (DECC) (now OEH) has provided *White Box-Yellow Box-Blakely's Red Gum Woodland Field Identification Guidelines* (DECC 2007). It is designed to provide background information to assist landholders to identify remnants of *White Box Yellow Box Blakely's Red Gum Woodland*.

These guidelines describe what an EEC is, describes *White Box Yellow Box Blakely's Red Gum Woodland*, where it is found and why it is important, and provides information about the different structural layers, variation in the community (from fire and other disturbances), the ability to regenerate and presents the list of characteristic species from the Final Determination. It notes that not all of the species listed in the Final Determination need to be present for a site to be considered Box-Gum Woodland.

It also provides four key characteristics that help to identify an area of *White Box Yellow Box Blakely's Red Gum Woodland*, which are equivalent to steps in the key shown above in the 'Identification guidelines' (**Section 4.5**). A notable difference is that affirmative answers to the four key characteristics only indicate that the site is considered *likely* to be *White Box Yellow Box Blakely's Red Gum Woodland*. As noted above, the assessment of characteristic species is provided in **Section 4.4**.

4.6 Conclusion

Based on the analysis of the data collected in the field with the description of the community in the Final Determination, in particular the list of characteristic species and soil type, it is concluded that the vegetation within the subject plots does not conform to the description of *White Box-Yellow Box-Blakely's Red Gum Woodland*.

5 Environment Protection and Biodiversity Conservation Act 1999

5.1 Introduction

This section addresses the EPBC Act listing of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. It considers the following documents:

- Commonwealth Listing Advice on *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (Threatened Species Scientific Committee 2006). This includes the listing advice and conservation advice.
- *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* EPBC Act policy statement (Department of the Environment and Heritage 2006a) and associated species list for the EPBC Act Policy Statement *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (Department of the Environment and Heritage 2006b).
- National Recovery Plan for *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (Department of Environment, Climate Change and Water NSW 2010).

The listing advice and conservation advice are the documents that define the ecological community under the EPBC Act. The listing advice contains a general description and condition classes, which includes characteristics that a patch of vegetation must have in order to be considered part of the listed ecological community.

Additionally, the policy statement includes a flowchart which represents the 'lowest condition at which patches are included in the listed ecological community' (Department of the Environment and Heritage 2006b). This is a graphical representation of the condition class characteristics in the listing advice.

Milledge (2012) applied the condition class characteristics to 4 plots, one of which was outside of the Narrabri Gas Project study area and is not considered further.

5.2 Listing advice

The listing advice provides a general description (Section 2) of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (Threatened Species Scientific Committee 2006). A comparison the data collected in the field against each paragraph in the general description is provided in **Table 10**.

Table 10: General description comparison

General Description paragraph	Assessment
<i>Box – Gum Grassy Woodlands and Derived Grasslands are characterised by a species-rich understorey of native tussock grasses, herbs and scattered shrubs, and the dominance, or prior dominance, of White Box, Yellow Box or Blakely's Red Gum trees. In the Nandewar Bioregion, Grey Box (<i>Eucalyptus microcarpa</i> or <i>E. moluccana</i>) may also be dominant or co-dominant. The tree-cover is generally discontinuous and consists of widely-spaced trees of</i>	The understorey within the subject plots is not considered to be species-rich nor is it characterised by native tussock grasses. Prober and Thiele (1993) note that 'floristic diversity at a site is generally high (up to 87 species or 63 native species in a 0.1 ha quadrat'. All plots except for BGW 1 contained <i>Eucalyptus blakelyi</i> as a dominant or co-dominant species.

General Description paragraph	Assessment
<p>medium height in which the canopies are clearly separated (Yates & Hobbs 1997).</p>	<p><i>E. melliodora</i> and <i>E. albens</i> were not recorded in any subject plots, however both are known to occur in other areas of the Pilliga Forest.</p> <p>The highest diversity in the subject plots was in plot 50 with 48 species (1 exotic and 47 native). However, most of the plots contained less than 30 species. Additional searches in some subject plots in a 0.1 ha area results in approximately four to seven more species, which still represents a lower diversity than that noted in Prober and Thiele (1993).</p> <p>The study area of the Narrabri Gas Project is not within the Nandewar Bioregion.</p> <p>Tree-cover in the subject plots ranged from discontinuous along larger creeks like Bohena Creek and continuous on smaller tributaries.</p>
<p>In its pre-1750 state, this ecological community was characterised by:</p> <ul style="list-style-type: none"> • a ground layer dominated by tussock grasses; • an overstorey dominated or co-dominated by White Box, Yellow Box or Blakely's Red Gum, or Grey Box in the Nandewar bioregion; and, • a sparse or patchy shrub layer. 	<p>The subject plots are not characterised by tussock grasses. Many of the plots are dominated by the graminoid <i>Lomandra longifolia</i> and the rhizomatous (underground stems) perennial grass <i>Imperata cylindrica</i>. The pre-1750 state of the vegetation sampled by the subject plots (VCA ID No. 399) is not known.</p> <p>The subject plots are not consistent with this component of the listing advice.</p> <p>The overstorey of most plots is dominated by <i>E. blakelyi</i>, although some plots are dominated by <i>Angophora floribunda</i> (plots 75) or <i>E. chloroclada</i> (plot BGW 1).</p> <p>Most plots have a sparse shrub layer, although some plots have dense patches of shrubs of <i>L. polygalifolium</i> subsp. <i>transmontanum</i> or <i>Callistemon linearis</i> which are typical of VCA ID No. 399 (Benson et al. 2010).</p>
<p>Associated, and occasionally co-dominant, trees include, but are not restricted to: Grey Box (<i>Eucalyptus microcarpa</i>), Fuzzy Box (<i>E. conica</i>), Apple Box (<i>E. bridgesiana</i>), Red Box (<i>E. polyanthemos</i>), Red Stringybark (<i>E. macrorhyncha</i>), White Cypress Pine (<i>Callitris glaucophylla</i>), Black Cypress Pine (<i>C. endlicheri</i>), Long-leaved Box (<i>E. goniocalyx</i>), New England Stringybark (<i>E. caliginosa</i>), Brittle Gum (<i>E. mannifera</i>), Candlebark (<i>E. rubida</i>), Argyle Apple (<i>E. cinerea</i>), Kurrajong (<i>Brachychiton populneus</i>) and Drooping She-oak (<i>Allocasuarina verticillata</i>) (Austin et al. 2002; Beadle 1981; Fischer et al. 2004; NSW</p>	<p>Other trees in subject plots included <i>E. conica</i> (Fuzzy Box), <i>C. endlicheri</i> (Black Cypress Pine), <i>Brachychiton populneus</i> (Kurrajong).</p> <p>These species are not restricted to <i>White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland</i> but also occur in other habitats and vegetation communities on the western slopes and plains.</p>

General Description paragraph	Assessment
<p>National Parks & Wildlife Service 2002; Prober & Thiele in press).</p>	
<p><i>This ecological community occurs in areas where rainfall is between 400 and 1200 mm per annum, on moderate to highly fertile soils at altitudes of 170 metres to 1200 metres (NSW Scientific Committee 2002).</i></p>	<p>As noted previously, the subject plots occur in an area that receives between 400 and 1200 mm of rainfall.</p> <p>However, the plots are not located on moderate to highly fertile soils. Instead, they are located on low to moderately low soil fertility, including siliceous sand and loamy sands along water courses.</p> <p>The soil fertility within the plots surveyed is not consistent the listing advice.</p> <p>The subject plots are above 170 m and below 1200 m altitude.</p>
<p><i>In general, White Box is more prevalent in the west, and Yellow Box – Red Gum in the east. A distinct exception is the outlying White Box woodlands in the upper Snowy River region in Victoria and adjacent southern New South Wales. Yellow Box and Blakely’s Red Gum are generally dominant on the Tablelands and form mosaics with White Box on the Eastern Slopes (Beadle 1981; Prober & Thiele in press). The understorey shows a more consistent pattern than the overstorey, with understorey species composition on the Tablelands differing from that on the Slopes (Prober & Thiele in press).</i></p>	<p>The location of the study area is outside of and north of the mapping in Prober and Thiele (2004). In addition it is outside and west of the area mapped in Prober (1996). However, it is likely to be located in the range of <i>E. albens</i> and <i>E. pilligaensis</i> (see Figure 13.7 in Beadle 1981).</p> <p>The subject plots are not located in either the tablelands or eastern slopes, and the vegetation dominated by <i>E. blakelyi</i> along creeks which were sampled by the subject plots does not form mosaics with <i>E. albens</i>.</p>
<p><i>The Box – Gum Grassy Woodland and Derived Grassland ecological community intergrades with Western Grey Box (<i>Eucalyptus microcarpa</i>) woodlands in the west (Prober and Thiele in press). Sites dominated by Western Grey Box (<i>E. microcarpa</i>) or Coastal Grey Box (<i>E. moluccana</i>) without Yellow Box, White Box or Blakely’s Red Gum as co-dominants are not considered to be part of the ecological community, except in the Nandewar Bioregion.</i></p>	<p>As noted in the previous section, the subject plots are outside of, and north of, the area surveyed by Prober and Thiele (2004). The vegetation sampled by the subject plots does not intergrade with <i>E. microcarpa</i> woodlands.</p>
<p><i>Thiele and Prober (2000) estimated that less than 0.1% of Grassy White Box Woodlands (a component of the Box – Gum Grassy Woodland and Derived Grassland ecological community) remains in a near-intact condition. Much of the original extent of the Box – Gum Grassy Woodland and Derived Grassland ecological community has been cleared for agriculture. In most of the areas that remain, grazing and pasture-improvement have effectively removed the characteristic understorey, leaving only the overstorey trees with an understorey dominated by exotic species (McIntyre et al. 2002; Prober & Thiele in press). In</i></p>	<p>Thiele and Prober (2000) note that much of the original extent of <i>White Box-Yellow Box-Blakely’s Red Gum Grassy Woodland and Derived Native Grassland</i> has been cleared for agriculture.</p> <p>The vegetation in and surrounding the subject plots has not been cleared for agriculture.</p> <p>The historical reason for this is likely to be because the soils are of low fertility and occur along drainage lines. The subject plots may have been used for grazing in the past, however, this has ceased and there is regeneration of the overstorey species.</p>

General Description paragraph	Assessment
<p>these areas, grazing has also largely prevented the regeneration of the overstorey species (Sivertsen 1993). Due to the high levels of clearing that have taken place, and continued grazing, large areas of healthy, regenerating overstorey are rare. Areas containing a number of mature trees or regenerating trees are important as they provide current and future breeding and foraging habitat for woodland animals, such as Regent Honeyeaters (<i>Xanthomyza phrygia</i>), Squirrel Gliders (<i>Petaurus norfolcensis</i>) and Superb Parrots (<i>Polytelis swainsonii</i>) (NSW Scientific Committee 2002).</p>	
<p>Kangaroo Grass (<i>Themeda triandra</i>, also known as <i>Themeda australis</i>) and Snow Grass (<i>Poa sieberiana</i>) were originally the dominant grasses across a large part of the ecological community's range, and are particularly sensitive to grazing pressure (Cole et al. 2004). Grazing tends to cause the loss of these grasses, along with other grazing-intolerant forbs, grasses, sedges and shrubs. These grazing-intolerant forbs include tall perennial herbs such as daisies (e.g. Yam Daisy (<i>Microseris lanceolata</i>)), lilies (e.g. Milkmaids (<i>Burchardia umbellata</i>)), pea plants (e.g. Australian Trefoil (<i>Lotus australis</i>)) and orchids (e.g. Purple <i>Diuris</i> (<i>Diuris punctata</i>)). Grazing can also have indirect effects upon other ground layer species through soil disturbance and physical changes to the soil such as compaction, nutrient enrichment, reduced water infiltration and erosion. These changes to the soil can facilitate and maintain weed invasions and make soil conditions unsuitable for native species regeneration (Prober et al. 2002a & 2002b; Yates & Hobbs 1997).</p>	<p>The subject plots have not been subject to the same grazing pressures as that described for woodlands on the western slopes. Therefore, if this vegetation was <i>White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland</i> it would be expected that the dominant ground layer species would be <i>Themeda australis</i> (Kangaroo Grass) and <i>Poa sieberiana</i> (Snow Grass). However, neither of these species was recorded within the subject plots. None of the cited tall perennial herbs were recorded but this could also be a result of habitat or distribution (e.g. <i>Burchardia umbellata</i> occurs further south).</p> <p>Although there are exotic species in the vegetation surveyed by the subject plots, it is considered unlikely that such a relatively light grazing pressure has impacted the soil, enriched nutrients or reduced water infiltration and erosion significantly. The soil in the subject plots are mostly siliceous sands and loamy sands that would not experience the same level of compaction from grazing that more fertile, heavier clay soils (which are characteristic of <i>White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland</i>) would. The establishment and persistence of weeds in the subject plots is more likely to be due to a combination of past logging, light grazing and continual soil movement and disturbance from flood events that promote the spread and importation of weed propagules.</p>
<p>As a consequence of these pressures, there are only a small number of areas remaining that retain a highly diverse understorey dominated by native, perennial tussock grasses. These areas are extremely rare, and usually quite small in size (Prober & Thiele 1995). They have often been cleared of trees and may no longer</p>	<p>The subject plots are not likely to be representative of the small number of areas remaining that retain a highly diverse understorey, even though they occur on public land that has not been utilised for domestic stock grazing or cropping. As noted above, the species</p>

General Description paragraph	Assessment
<p><i>possess an overstorey. However, these remnants can be relatively intact despite the absence of trees. Generally an intact native understorey can resist large-scale weed invasion. For example, when established at high densities, Kangaroo Grass can suppress invasive exotic perennial grass species (Cole et al. 2004). This type of understorey can also provide important habitat for fauna, such as small mammals, reptiles and insects, and foraging habitat for larger mammals (Siversten 1993). Areas of high understorey biodiversity tend to occur on public land that has not been utilised for domestic stock grazing or cropping. Examples include cemeteries and road verges, some town commons, or travelling stock routes or reserves (Prober & Thiele in press).</i></p>	<p>diversity is relatively low, despite the relatively lower levels of intensity of disturbance.</p>
<p><i>Given the occurrence of Box – Gum Grassy Woodlands and Derived Grasslands on the best soils, and therefore the most sought-after agricultural land, very little of the ecological community is reserved. The reserved areas tend to be shrubbier and occur on less arable soils. Remnants on the most fertile soils are the least commonly reserved (Thiele & Prober 2000). Prober (1996) noted that remnants in the existing reserves did not represent the natural variation in Grassy White Box Woodland, but favoured communities on poorer soils, i.e. soils classed as unsuitable for agriculture, generally associated with steeper slopes, or shallower soils and/or areas with high shrub abundance. While the ecological community does occur in a number of reserves, most reserves contain only small occurrences, and these remnants have usually been modified by historical land use (NSW Scientific Committee 2002; Prober & Thiele 1993).</i></p>	<p>The subject plots do not occur within the best soils within the region. The Pilliga Forests are known to support soils of relatively low fertility, compared to the surrounding landscapes (slopes and plains with clays). The subject plots are not arable and do contain more shrubs, but this is also typical of the majority of the other vegetation communities in the Pilliga Forest that are also not <i>White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland</i>.</p>
<p><i>Shrubs can occur naturally in grassy woodlands, and can form an important part of the Box – Gum Grassy Woodland and Derived Grassland ecological community, however, on poorer soils throughout its range, this ecological community grades into shrubby woodlands (Prober & Thiele 1993). This can lead to confusion in recognising the listed ecological community, and the following can be used to determine if a remnant is included in the listed ecological community or if it is a shrubby woodland. Shrub cover in this ecological community is naturally patchy, and shrubs may be dominant only over a very localised area. Shrub cover should therefore be assessed over</i></p>	<p>Prober and Thiele (1993) note that 'on more marginal sites, usually with shallow or sandy soils, shrubs become more abundant in the understorey'.</p> <p>The soil in the subject plots is siliceous sand to loamy sand and is of low fertility, compared to the soil where it is known that <i>White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland</i> occurs.</p> <p>In the subject plots the shrub cover is generally low (less than 5%) although plot 34 has a shrub cover of 20%. Dominant species in plot 34 were <i>Cassinia arcuata</i>, <i>Brachyloma daphnoides</i> and <i>Hibbertia</i></p>

General Description paragraph	Assessment
<p><i>the entire remnant, not just in a localised area. A remnant with a significant ground layer of tussock grasses, and where the distribution of shrubs is scattered or patchy, is part of the ecological community. In shrubby woodlands, the dominance of native tussock grasses in the ground layer of vegetation is lost. Therefore, a remnant with a continuous shrub layer, in which the shrub cover is greater than 30%, is considered to be a shrubby woodland and so is not part of the listed ecological community. Remnant attributes, such as shrubbiness, should be measured on a scale of 0.1 hectares or greater.</i></p>	<p><i>species.</i> The low cover of shrubs is not atypical of vegetation along Bohena Creek and its tributaries and the surrounding vegetation.</p>

In summary, the vegetation in the subject plots is not consistent with the general description of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* in the listing advice in the following areas:

- The subject plots are located on low to moderately low fertility soil and not on the best soils or on moderate to high fertile soils on the western slopes, which is where *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* has been described as occurring.
- The ground layer remains largely intact and is not dominated by tussock grasses.
- The diversity of the ground layer is relatively low, despite the fact that pressures such as grazing, cropping and fertilizers have not been high, and their effects (soil compaction, weed invasion) have also not been significant.
- The subject plots are located along riparian areas within ephemeral sandy creeks between woodland and forest dominated by *E. crebra* and *E. chloroclada* and not in areas of deep fertile soils or in valleys that are dominated by *E. blakelyi* within a mosaic of *E. albens* woodlands.

Section 3 of the Listing Advice discusses the national extent of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* and cites the NSW government Scientific Committee Final Determination. This has been discussed above. It is noted that the federally listed community excludes some areas that are state-listed because they are 'heavily degraded and do not retain sufficient values to be considered part of the ecological community'. The subject plots are within the known range of the community.

Section 4 of the Listing Advice outlines the condition classes for *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. This section notes that areas without a 'substantially native understorey are degraded and are no longer a viable part of the federally listed ecological community'.

Listed ecological communities usually contain key diagnostic characteristics and condition classes, which are designed so that a listed community can be identified in the field. These two tests (based on characteristics and condition) are necessarily related. Once a community type has been identified through comparison of the key diagnostic characteristics with the data collected in the field (e.g. location, soils, dominant canopy, and species assemblage) then its condition would need to be assessed to determine

if it is part of a listed community. As noted above, some degraded areas have insufficient value, and subject to condition class assessment, are excluded from the listed community.

The listing advice for *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* does not contain key diagnostic characteristics. Therefore, identification of this community type must be based on a comparison of features in the general description (including a review of the cited literature) with the data collected in the field. If the site in question can be said to conform to the general description, then assessment of its condition should be undertaken, based on the condition classes in the listing advice, to determine if the community still retains sufficient value to be part of the listed ecological community.

As noted above, it is concluded that the vegetation sampled by the subject plots does not conform to the community type described as *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* in the general description of the listing advice. Therefore, comparison of the data collected in the field against the condition class is not required.

Condition classes for which a patch of vegetation would be considered to be the listed community include the following:

- A patch must have a predominantly native understorey.
- A patch only needs to be 0.1 ha in size.
- An understorey patch (with or without an overstorey) must have a high level of native species diversity defined as having a ground layer in which the perennial vegetation is dominated by native species, and which contains at least 12 native, non-grass understorey species (such as forbs, shrubs, ferns, grasses and sedges)
- At least one of the understorey species should be an important species (e.g. grazing-sensitive, regionally significant or uncommon species; such as *Themeda australis* (Kangaroo Grass) or orchids) in order to indicate a reasonable condition

If patches do not meet these conditions they can still be considered to be the listed community if:

- They have a predominantly native understorey, are two hectares or above in size and have either natural regeneration of the overstorey species or 20 or more mature trees per hectare.

The condition criteria are 'the minimum level at which patches are to be included in the listed ecological community'. However, these condition criteria could be applied to data collected in the field to any number of very diverse and different vegetation communities. This is because species and structural characteristics used in the condition class assessment are widespread features that could occur in various communities. But this would not necessarily mean that the vegetation type under discussion is the listed community.

It is clear that the condition classes presuppose that the patch of vegetation under consideration is firstly identified as the correct vegetation community before data can be compared against the condition classes. Therefore, the condition classes are not relevant to the determination of whether the vegetation sampled by the subject plots are *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* in the general description of the listing advice.

The remaining sections of the Listing Advice are not directly relevant to the identification of this community in the field, but include information about its listing as a CEEC and conclusion and recommendation to list this community as critically endangered under the EPBC Act.

5.3 Policy statement and species list

The policy statement (Department of the Environment and Heritage 2006a) is intended to provide a guide and information for stakeholders on why the ecological community has been listed, what the ecological community is and how to identify it. It summarises the information provided under Section 2 (General Description) of the listing advice, explains why this community is important as habitat (it provides habitat for a large number of plants and animals including rare and threatened species), explains why it has been listed, describes the range of the community (a coarse-scale map is provided), provides information to help identify the community and lastly discusses rehabilitation and management implications. Associated with the policy statement is a species list which has been compiled to help the use of the flowchart contained in the policy statement (Department of the Environment and Heritage 2006b).

The flowchart is designed to help stakeholders determine if their land has an area of the listed community on it. The introduction to the flowchart states that it '*represents the lowest condition at which patches are included in the listed ecological community*' (Department of the Environment and Heritage 2006a). In addition, the flowchart is referred to in the previous section in which it is explained that '*heavily degraded areas no longer retain sufficient values to merit protection under the EPBC Act*'.

The steps in the flow chart are identical to the condition class criteria shown in the listing advice apart from two changes:

- The first step requires an assessment of the presence or previous presence of at least one of the more common overstorey species of the community.
- The list of important species is defined and reference is made to that list (Department of the Environment and Heritage 2006b).

The condition criteria in the listing advice do not explicitly list the dominant species. This information is contained in the general description of the listing advice. As noted above, there are a number of different vegetation communities that are not the listed community, in which the dominant species could be one of those cited in the flowchart (*E. albens*, *E. melliodora*, *E. blakelyi*, *E. macrocarpa*, *E. moluccana*). The use of only the flowchart to identify a particular vegetation community could, therefore, result in the misidentification of the listed community.

This flowchart is not considered to be a key diagnostic characteristic flowchart, but instead, a means of assessing the condition of a patch of vegetation that has previously been identified as the community type that conforms to *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*.

The associated species list (532 species) is designed to provide information about the plant species that can be found in *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. This list provides information about this community but it is not a list of diagnostic (species that differentiate the community from other communities) or characteristic species (species that occur the most frequently in the community) that could be used to determine if vegetation at a site is that community type in the same way as diagnostic or characteristic species.

In conclusion, it is considered that the policy statement provides some general information regarding the listed community and provides a flowchart to assist users apply the condition class criteria in the listing advice. Therefore, it should be used as a guide to assess the condition of a patch of vegetation once it has been determined that the patch satisfies the general description of the community (Section 2) in the listing advice.

5.4 Review of Milledge (2012)

Milledge (2012) asserts that vegetation sampled in four areas in the Pilliga forest is part of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. One of those areas (Scratch Road) supported *E. albens*, and it is possible that it could potentially occur on more fertile soils. However, this is outside of the study area for the Narrabri Gas Project and is not reviewed in this report.

Milledge (2012) assessed potential EECs through the collection of information on the community's patch size and a detailed description of the species composition of the upper, mid and ground-cover vegetation strata. In Appendix 2 of Milledge (2012), plant species presence/absence data is provided for four sites. Species for each site are divided into upper stratum dominants, upper stratum sub-dominants, mid stratum species, ground cover species and important species.

The footnotes to the appendix are as follows:

- Qualifying criteria under EPBC Act listing of CEEC include presence of one or more of *Eucalyptus albens*, *E. melliodora* or *E. blakelyi* among the most common overstorey species'
- Qualifying criteria under EPBC Act listing of CEEC include presence of 12 or more native understorey species (excluding grasses) and at least one "important" species'.
- Included in EPBC Act listing of CEEC as indicative species

The first footnote is a paraphrase of the first step in the flowchart of the policy statement and the second footnote is a paraphrase of a step in the flowchart in the policy statement. However, the term 'qualifying criteria' does not appear in the listing advice or in the policy statement. The third footnote refers to 'indicative species' and this term is also not found in the listing advice, policy statement or associated species list.

Data collected in the field by Milledge (2012) has been compared to the condition class criteria, rather than the general description given in the listing advice. The term 'qualifying criteria' has been mistakenly referred to the listing advice and suggests that the aim of the analysis was to identify whether a patch of vegetation qualified to be part of the listed community.

Therefore, Milledge (2012) has not adequately identified the type of vegetation community at the sites sampled with reference to the general description and appears to have used the condition class criteria to provide evidence that such vegetation is the listed community. As noted above, use of the condition class criteria in this way is erroneous. The conclusions that vegetation at the sample sites is the listed community is not supported by evidence provided in the report.

5.5 Conclusion

Based on the review of the EBPC Act listing advice and policy statement it is concluded that the vegetation sampled by the subject plots is not *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. This is because the vegetation and site characteristics including soil fertility do not conform to the description of this community provided in the listing advice.

In addition, the conclusions of Milledge (2012) regarding the presence of the listed community at three sites in the study area are not supported by evidence in that report.

6 Conclusion

Based on the analysis of plot data in vegetation dominated by *E. blakelyi* within the study area of the Narrabri Gas Project with reference to the BC Act listing of *White Box Yellow Box Blakely's Red Gum Woodland* and the EPBC Act listing of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*, it is concluded that neither of these listed communities occur.

This is because the vegetation dominated or co-dominated by *E. blakelyi* within the study area does not have a species assemblage consistent with the BC Act or EPBC Act listings and does not occur on 'relatively fertile' soils. Instead the vegetation conforms more readily to the Benson et al. (2010) VCA ID No. 399 *Red gum – Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion* which occurs on low to moderately fertile soil.

For the EPBC Act listed community, firstly it must be determined if a patch of vegetation conforms with the general description of the CEEC in the listing advice prior to determining whether the patch satisfies the condition class criteria in determining if the patch of vegetation is part of the listed community.

Therefore, the assertion by Milledge (2012) that the BC Act and EPBC Act listed community occurs in the study area based on the condition class criteria alone is not supported by the information provided in the BC Act Final Determination or the EPBC Act listing advice and policy statement.

References

Australian Government 2005 (a). *Including in the list in the critically endangered category: White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Deleting from the list in the endangered category: Grassy White Box Woodlands.* Legislative instrument. Accessed 19 November 2013. <http://www.comlaw.gov.au/Details/F2006L01478/Download>

Australian Government 2005 (b). *Including in the list in the critically endangered category: White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Deleting from the list in the endangered category: Grassy White Box Woodlands.* Explanatory statement. Accessed 19 November 2013 <http://www.comlaw.gov.au/Details/F2006L01478/Download>

Beadle, N.C.W. 1981. *The Vegetation of Australia*. Cambridge University Press, Cambridge.

Benson, J.S., Richards, P.G., Waller, S. and Allen, C.B. 2010. New South Wales Vegetation classification and Assessment: Part 3 Plant communities of the 457 NSW Brigalow Belt South, Nandewar and west New England Bioregions and update of NSW Western Plains and South-western Slopes plant communities, Version 3 of the NSWVCA database. *Cunninghamia*.11: 457-579.

Conn, B.J 1992. 'Oxalis perennans Haw.' in *Flora of New South Wales Volume 3*, New South Wales University Press, Sydney.

Department of Environment (DoE) 2013. White Box-Yellow Box-Blakely's Red Gum Woodland and Derived Grassland SPRAT profile. Last updated 16 July 2013. Accessed 19 November 2013. <http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=43>

Department of Environment and Conservation (DEC). 2005. *Interpreting and identifying endangered ecological communities in the Sydney Basin*. Environmental Impact Assessment Guidelines. New South Wales.

Department of Environment and Climate Change (DECC) 2007. *White Box-Yellow Box-Blakely's Red Gum Woodland Field Identification Guidelines*. <http://www.environment.nsw.gov.au/resources/threatenedspecies/EECWhiteboxLowRes.pdf>

Department of Environment and Climate Change (DECC) 2008. *Landscapes (Mitchell) of NSW - Version 3*. DECC Sydney, NSW.

Department of Environment, Climate Change and Water NSW 2010. National Recovery Plan for White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Department of Environment, Climate Change and Water NSW, Sydney.

Department of the Environment and Heritage (DEH) 2006(a). *White Box-Yellow Box-Blakely's Red Gum grassy woodlands and derived native grasslands EPBC Act policy statement*. <http://www.environment.gov.au/system/files/resources/be2ff840-7e59-48b0-9eb5-4ad003d01481/files/box-gum.pdf>

Department of the Environment and Heritage (DEH) 2006(b). Species List for the EPBC Act Policy Statement *White Box-Yellow Box-Blakely's Red Gum grassy woodlands and derived native grasslands*. Last updated 22 May 2006. <http://www.environment.gov.au/system/files/resources/be2ff840-7e59-48b0-9eb5-4ad003d01481/files/box-gum-species.pdf>

- Department of Mineral Resources (DMR) 2003. *Statewide (NSW) Digital Geology 1:250 000*. DMR, NSW.
- Eco Logical Australia (ELA) 2009. *A Vegetation Map for the Namoi Catchment Management Authority*. Report prepared by Eco Logical Australia for the Namoi Catchment Management Authority.
- El-Shaarawi, A. and Piegorisch, W. 2002. *Encyclopedia of Environmetrics*. John Wiley & Sons, Ltd Press, West Sussex.
- Harden, G. J. (ed.) (1990-1993, 2002). *Flora of New South Wales Volumes 1 to 4*, New South Wales University Press, Sydney.
- Keith, D.A. (2004). *Ocean Shores to Desert Dunes: the Native Vegetation of New South Wales and the ACT*. NSW Department of Environment and Conservation: Hurstville.
- McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS 1998. *Australian Soil and Land Survey Field Handbook*. Australian Collaborative Land Evaluation Program, Canberra.
- Milledge, D. 2012. *National Significance. The ecological values of the Pilliga east forest and the threats posed by coal seam gas mining 2011-2012*. A report prepared for the Northern Inland Council for the Environment and the Coonabarabran and Upper Castlereagh Catchment and Landcare Group.
- Moore, C.W.E. 1953a. The vegetation of the south-eastern Riverina, New South Wales. I. The climax communities. *Australian Journal of Botany* 1, 489-547.
- Moore, C.W.E. 1953b. The vegetation of the south-eastern Riverina, New South Wales. II. The disclimax communities. *Australian Journal of Botany* 1, 548-567.
- NSW Scientific Committee 2002. *White Box Yellow Box Blakely's Red Gum Woodland – endangered ecological community listing*. NSW Scientific Committee – Final Determination. Last updated 28 February 2011.
<http://www.environment.nsw.gov.au/determinations/BoxgumWoodlandEndComListing.htm>
- NSW Scientific Committee 2010. *Guidelines for interpreting listing criteria for species, populations and ecological communities under the NSW Threatened Species Conservation Act*. NSW Scientific Committee, November 2010.
- NSW National Parks and Wildlife Service (NPWS) 2000. *Brigalow Belt South: Regional Assessment (Stage 1) - Report on Preliminary Fauna Survey of Pilliga and Goonoo Forests, November 1999 to January 2000*. Report prepared for the Resource and Conservation Assessment Council, NSW Western Regional Assessments
- Office of Environment and Heritage (OEH) 2013. Estimated inherent fertility of soils in the New England/North West Strategic Regional Landuse area. February 2013.
- Office of Environment and Heritage (OEH) 2017. *White Box Yellow Box Blakely's Red Gum Woodland – profile*. Last Updated 7 September 2017. Accessed 12 December 2017.
<http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10837>
- NSW National Parks and Wildlife Service (NPWS), Undated (a). *White Box-Yellow Box-Blakely's Red Gum (Box-Gum) Woodland fact-sheet*. NSW Threatened Species Unit.
<http://www.environment.nsw.gov.au/resources/nature/Box-gumFactsheet.pdf>

NSW National Parks and Wildlife Service (NPWS), Undated (b). *Identification Guidelines for Endangered Ecological Communities. White Box-Yellow Box-Blakely's Red Gum (Box-Gum) Woodland*. NSW Threatened Species Unit. <http://www.environment.nsw.gov.au/resources/nature/box-gumIdGuidelines.pdf>

Prober, S.M. 1996. Conservation of the grassy white box woodlands: rangewide floristic variation and implications for reserve design. *Australian Journal of Botany* 44, 57-77.

Prober, S.M. & Thiele, K.R. 1993. The ecology and genetics of remnant grassy white box woodlands in relation to their conservation. *Victorian Naturalist* 110, 30-36.

Prober, S.M. & Thiele, K.R. 1995. Conservation of grassy white box woodlands: relative contributions of size and disturbance to floristic composition and diversity of remnants. *Australian Journal of Botany* 43, 349-366.

Prober, S.M. & Thiele, K.R. 2004. Floristic patterns along an east-west gradient in grassy box woodlands of Central New South Wales. *Cunninghamia*. 8(3): 306-325.

Threatened Species Scientific Committee 2006. Commonwealth Listing Advice on White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Accessed 19 November 2013. <http://www.environment.gov.au/biodiversity/threatened/communities/pubs/box-gum.pdf>

Threatened Species Scientific Committee 2010. *Advice on the presence of hybrids in listed ecological communities*. <http://www.environment.gov.au/system/files/resources/bc92c433-46c8-4792-a6a6-a8bfec4eebb2/files/advice-hybrids.pdf>

Appendix A: Plot species list

Cover/abundance was recorded according to the following scale:

- + = few, small cover (<5%)
- r = solitary, small cover (<5%)
- 1 = numerous (<5%)
- 2 = 5-25%
- 3 = 25-50%
- 4 = 50-75%
- 5 = <75%

In plots where cover-abundance was not recorded, an 'X' indicates presence

Table 11: Plot species list

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Acacia caroleae</i>		r	+	+	+	+	+	r	+	X	X						X
<i>Acacia deanei</i> subsp. <i>deanei</i>		r	+	+	+	+	+	r	+	X	X						
<i>Acacia leiocalyx</i> subsp. <i>leiocalyx</i>		+															
<i>Acacia polybotrya</i>									1								X
<i>Acacia parvifolia</i>									+								
<i>Acacia</i> sp.									+				X				
<i>Acacia spectabilis</i>									+		X	X		X	X	X	X
<i>Ajuga australis</i>								r							X		X
<i>Alternanthera denticulata</i>										X							
<i>Amyema pendulum</i>							+										
<i>Anagallis arvensis</i>	*				r	r		+									
<i>Angophora floribunda</i>				r	1				2	X	X				X	X	X
<i>Argemone ochroleuca</i>	*							+		X							
<i>Aristida acuta</i>							r										
<i>Aristida caput-medusae</i>						1		+			X		X	X			
<i>Aristida jerichoensis</i>																	X

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Aristida ramosa</i>							+										
<i>Aristida</i> sp.		+		+	+	+			1						X		
<i>Arundinella nepalensis</i>		2	+			r	2	1	+		X	X					X
<i>Rytidosperma setacea</i>								1				X					X
<i>Austrostipa scabra</i> subsp. <i>scabra</i>				1	+	1				X							
<i>Austrostipa</i> sp.								1									
<i>Austrostipa verticillata</i>			1	+	1	1				X			X				
<i>Avena</i> sp.	*	r															
<i>Babingtonia cunninghamii</i>																	X
<i>Bidens pilosa</i>	*							+									
<i>Bidens subalternans</i>	*		r	+	+	+				X			X				
<i>Billardiera</i> sp. (unidentified)								r									
<i>Boerhavia coccinea</i>					+												
<i>Boerhavia dominii</i>								r									
<i>Boerhavia</i> sp.						+											
<i>Bothriochloa</i> sp.							r										
<i>Brachychiton populneus</i> subsp. <i>populneus</i>								r									
<i>Brachyloma daphnoides</i>									r		X			X		X	
<i>Brunonia australis</i>							+										
<i>Caesia parviflora</i>																	X
<i>Calandrinia eremaea</i>						+											
<i>Callistemon linearis</i>			+		+	+				X							
<i>Callitris endlicheri</i>				+							X	X					
<i>Callitris glaucophylla</i>		1	r			2	1						X			X	
<i>Calotis cuneifolia</i>							+					X					
<i>Calytrix tetragona</i>							r		+		X			X			
<i>Cassinia arcuata</i>									+	X	X	X		X	X	X	X
<i>Cassytha glabella</i>							r										
<i>Cenchrus incertus</i>	*									X							
<i>Centella asiatica</i>		r															

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Cheilanthes sieberi</i> subsp. <i>sieberi</i>							+	+				X	X		X	X	
<i>Cheilanthes</i> sp.				r	+												
<i>Chondrilla juncea</i>	*			+	+	+				X			X				
<i>Chrysocephalum apiculatum</i>		+	+	r		1	+	+									
<i>Commelina cyanea</i>								r				X					X
<i>Conyza bonariensis</i>	*							+									X
<i>Conyza</i> sp.	*									X							
<i>Crassula</i> sp. (exotic)	*				+	+											
<i>Crotalaria mitchellii</i>				r		r											
<i>Cymbopogon refractus</i>		1	+			1	+		1		X	X			X	X	X
<i>Cynodon dactylon</i>	*		1	1	+	+				X			X				
<i>Cyperus gunnii</i> subsp. <i>gunnii</i>		+															
<i>Cyperus haspan</i>																	X
<i>Cyperus</i> sp.			+												X	X	X
<i>Cyperus vaginatus</i>			+	+						X							
<i>Daucus glochidiatus</i>		+						r		X							
<i>Dianella longifolia</i>		+															
<i>Dianella revoluta</i>		r					r		+		X	X				X	X
<i>Digitaria ammophila</i>							r										
<i>Digitaria diffusa</i>							r	r									X
<i>Dodonaea viscosa</i> subsp. <i>mucronata</i>																	X
<i>Echinopogon caespitosus</i>																	X
<i>Echinopogon ovatus</i>																	X
<i>Einadia</i> sp.						+											
<i>Entolasia stricta</i>																	X
<i>Epaltes australis</i>																	X
<i>Epilobium hirtigerum</i>										X							
<i>Eragrostis brownii</i>		1					+				X	X		X		X	
<i>Eragrostis curvula</i>	*	3								X							
<i>Eragrostis lacunaria</i>		+															

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Eragrostis</i> sp.																	X
<i>Eucalyptus blakelyi</i>		2	+	2	2	2		2	2	X	X	X	X	X	X	X	X
<i>Eucalyptus chloroclada</i>							2		r								
<i>Eucalyptus conica</i>								r									
<i>Euchiton sphaericus</i>																	X
<i>Fimbristylis dichotoma</i>																	X
<i>Fumaria</i> sp.	*							r									
<i>Gahnia aspera</i>					r	r			+	X	X	X	X	X	X	X	X
<i>Glycine canescens</i>		+						+									
<i>Glycine clandestina</i>						r	r					X	X			X	X
<i>Glycine</i> sp.				r		+				X							
<i>Goodenia glabra</i>							+					X				X	X
<i>Haloragis heterophylla</i>							r					X					X
<i>Hardenbergia violacea</i>								r									
<i>Heliotropium</i> sp.	*			+													
<i>Hibbertia obtusifolia</i>																	X
<i>Hypochaeris radicata</i>	*	+						+									
<i>Imperata cylindrica</i>		3	3	+		2				X			X				
<i>Juncus aridicola</i>		+				+				X							
<i>Juncus psammophilus</i>			1	+	+												
<i>Juncus</i> sp.									+								
<i>Lepidium africanum</i>	*									X							
<i>Leptospermum polygalifolium</i> subsp. <i>transmontanum</i>		1			r		r		2		X	X					
<i>Leucopogon biflorus</i>						+						X					
<i>Leucopogon muticus</i>							r							X			
<i>Lissanthe strigosa</i>							r					X					X
<i>Lomandra leucocephala</i> subsp. <i>leucocephala</i>							+				X						
<i>Lomandra longifolia</i>		2	1	2	2	2	3	3	1				X		X	X	X
<i>Lomandra multiflora</i>							r		+			X		X		X	X
<i>Macrozamia communis</i>																	X

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Marrubium vulgare</i>	*				+												
<i>Melichrus urceolatus</i>						r	+				X	X		X	X	X	X
<i>Melinis repens</i>	*	r															
<i>Microlaena stipoides</i>							1	+	1	X				X	X	X	X
<i>Mirbelia pungens</i>																	X
<i>Oenothera</i> sp.	*		r	+	r												
<i>Opuntia aurantiaca</i>	*	+															
<i>Opuntia</i> sp.	*		+			1											
<i>Opuntia stricta</i>	*	r		r	+	r		r					X				
<i>Oxalis perennans</i>										X							
<i>Oxalis</i> sp.	*							+									
<i>Panicum simile</i>							r				X	X		X		X	X
<i>Paspalum dilatatum</i>	*									X							
<i>Persicaria decipiens</i>										X							
<i>Persicaria prostrata</i>			r		r												
<i>Persoonia sericea</i>																	X
<i>Phragmites australis</i>		1	+														
<i>Platysace ericoides</i>																	X
<i>Podolepis neglecta</i>							r								X		
<i>Podolepis</i> sp. (unidentified)						+							X				
<i>Polycarpon tetraphyllum</i>	*									X							
<i>Pomax umbellata</i>																	X
<i>Rumex brownii</i>								+		X			X				
<i>Senecio prenanthoides</i>		r															
<i>Setaria</i> sp.	*									X							
<i>Sida cunninghamii</i>																	X
<i>Silene</i> sp. (unidentified)	*					r											
<i>Sonchus oleraceus</i>	*							+									
<i>Sporobolus creber</i>										X							
<i>Sporobolus</i> sp. (unidentified)				1													

Species Name	Exotic	RG1	N24	N23	N22	N20	BGW 1	BGW 2	W13	57	75	89	20	25	31	34	50
<i>Styliidium eglandulosum</i>							r							X			
<i>Styphelia triflora</i>						r											
<i>Swainsona galegifolia</i>										X							
<i>Swainsona</i> sp.					+												
<i>Trachymene</i> sp. (unidentified)						+											
<i>Urtica incisa</i>					r					X			X				
<i>Verbascum thapsus</i>	*							r									
<i>Verbena</i> sp.	*		r		r												
<i>Verbena tenuisecta</i>	*	1	1	1	1	1		2		X			X				
<i>Vernonia cinerea</i>																	X
<i>Vittadinia dissecta</i> var. <i>hirta</i>			+	+									X				X
<i>Vittadinia muelleri</i>								+									
<i>Vittadinia</i> sp.						+			r								
<i>Vulpia</i> sp. (unidentified)	*	+			+	1				X							
<i>Wahlenbergia communis</i>							+										X
<i>Wahlenbergia gracilis</i>								r			X						
<i>Wahlenbergia</i> sp. (unidentified)		+		r						X					X	X	
<i>Xanthium occidentale</i>	*									X							

Shaded species are characteristic species in the Scientific Committee Final Determination (BC Act)

Appendix B: BC Act list of characteristic species

Table 12: BC Act list of characteristic species

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Acacia buxifolia</i>	Shrub	Erect or spreading shrub	?CC, NT, CT, ST, NWS, CWS, SWS, NWP	Widespread but especially common on the Slopes	No	Yes
<i>Acacia implexa</i>	Shrub	Erect or spreading tree	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Widespread, from coastal areas inland to the Deniliquin district	No	No
<i>Acacia paradoxa</i>	Shrub	Erect or spreading shrub	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Widely distributed from the coast west to Moree and Griffith areas	No	No
<i>Alectryon oleifolius</i>	Tree	Small tree	NWS, CWS, NWP , SWP, NFWP, SFWP	Widespread in semi-arid areas, west from upper Hunter Valley	No	No
<i>Allocasuarina verticillata</i>	Shrub/tree	Dioecious small tree	CC, SC, CT, ST, CWS, SWS, NWP , SWP	Usually grows in grassy woodland, forming pure stands or amongst eucalypts; also on rocky sea-coasts and on dry ridges	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				inland. South from near Cobar on rocky hills, on coastal shale patches near Sydney and southwards		
<i>Aristida behriana</i>	Grass	Tufted perennial, flowers summer or in response to rain	NT, CT, ST, NWS, CWS, SWS, NWP , SWP, SFWP	Grows in grassland and open woodland on loamy soils	No	No
<i>Aristida ramosa</i>	Grass	Tussocky perennial, flowers in summer	"NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in woodland on poor soils	94, BGW1	Yes
<i>Asperula conferta</i>	Herb	Perennial herb	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP	Grows in woodland, forest and grassland, common and widespread	No	Yes
<i>Atalaya hemiglauca</i>	Small tree	Small tree	NWS, NWP , SWP, NFWP	Widespread in mixed open forest, sometimes the dominant species,	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				northern parts of N.S.W		
<i>Rytidosperma auriculata</i>	Grass	Slender perennial	ST, CWS, SWS, SWP	Usually grows on open plains with loamy or clay soil, in natural pastures	No, not in range	No
<i>Rytidosperma bipartita</i>	Grass	Densely caespitose perennial	NC, CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Usually on heavy clay or loamy soils in open country	No	Yes
<i>Rytidosperma racemosa</i>	Grass	Caespitose perennial	CC, NT, CT, ST, SWS	Grows in grassland, woodland and forest	No, not in range	No
<i>Rytidosperma richardsonii</i>	Grass	Densely caespitose perennial	CC, NT, CT, ST, CWS, SWS, NWP , NWS	Common in natural pastures and is potentially useful species as a fodder grass; cultivated for use in horticulture and for stabilising roadsides	No	No
<i>Austrostipa aristiglumis</i>	Grass	Caespitose perennial	NC, CC, NT, CT, NWS, CWS, SWS, NWP , SWP	Grows on heavy soils west of the Great Dividing Ra	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Austrostipa blackii</i>	Grass	Caespitose perennial	NT, CT, ST, CWS, SWS, NWP , SWP, SFWP	Widespread on heavier soils, heavily grazed	No	No
<i>Austrostipa nodosa</i>	Grass	Caespitose perennial	CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread, mostly on heavier soils of winter rainfall areas	No	No
<i>Austrostipa scabra</i>	Grass	Caespitose perennial	NC, CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread	N23, N22, N20, 57	Yes
<i>Bothriochloa macra</i>	Grass	Caespitose to decumbent perennial	C, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Widespread in overgrazed pastures	BGW1 (<i>Bothriochloa</i> sp.)	Yes
<i>Brachychiton populneus</i>	Tree	Evergreen tree to 20 m high	NC, CC, SC, NT, CT, NWS, CWS, SWS, NWP , SWP	Widespread in forest and woodland, especially on the Western Slopes. Often grown for shade and fodder	BGW2	Yes
<i>Brachyloma daphnoides</i>	Shrub	Erect shrub	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP	Grows in heath, dry sclerophyll forest and	N13, 75, 94, 25, 34	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				woodland on sand, sandy loams or occasionally more clayey soils; common		
<i>Bracteantha viscosa</i>	Herb	Usually annual, sometimes perennial. Sticky everlasting erect, viscid herb	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in open woodland and sclerophyll forest, usually on sandy to sandy loam soils, west to Deniliquin district	No	No
<i>Brunoniella australis</i>	Herb	Prostrate or erect	NC, CC, CT, NWS, CWS, NWP	Grows in sclerophyll forest and woodland; widespread, especially on Slopes, north from Camden	No	Yes
<i>Bulbine bulbosa</i>	Herb	Perennial herb	NC, CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Found in damp areas in woodland, grassland and sclerophyll forest	No	No
<i>Bursaria spinosa</i>	Shrub or tree	Shrub or small to medium tree	NC, CC, SC, NT, CT, ST, NWS,	Widespread and common throughout the	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
			CWS, SWS, NWP , SWP	State and all other states, except Western Australia and Northern Territory		
<i>Callitris endlicheri</i>	Tree	Tree	NC, CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Usually found on stony hills or ridges, common, from the plains to the coastal ranges	N23, 75, 89, 94	Yes
<i>Callitris glaucophylla</i>	Tree	Tree to 20 m high	NC, SC, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread, found mostly on sandy soils, from isolated individuals to extensive forests, especially in inland districts	RG1, N24, N20, BGW1, 20, 34	Yes
<i>Capparis mitchellii</i>	Shrub	Shrub 3-4 m high, often scrambling and spinose in juvenile stages	NWS, NWP , NFWP, SFWP	Grows mostly as scattered individuals. Fruit edible but not very palatable	No	No
<i>Cassinia longifolia</i>	Shrub	Aromatic and sticky shrub 1.2- 2.5 m high	CC, SC, CT, ST, CWS, SWS	Grows in sclerophyll forest and disturbed sites, on shale or	No, not in range	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				granite soils, often on ridges; south from Orange		
<i>Cassinia quinquefaria</i>	Shrub	Shrub 1-3 m high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in open sites in dry sclerophyll forest and woodland on a variety of soils; widespread	No	No
<i>Cheilanthes sieberi</i>	Fern	Grows amongst rocks, widespread in open forest or woodland	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP, LHI	Occurs throughout much of N.S.W.; all States, Lord Howe Island, Norfolk Island, New Zealand and New Caledonia	BGW1, BGW2, 89, 94, 20, 31, 34	Yes
<i>Chloris truncata</i>	Grass	Erect glabrous perennial to 0.5 m high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP, *LHI	Grows on many soil types and communities but more common on red or black earths	No	Yes
<i>Chloris ventricosa</i>	Grass	Erect, stoloniferous, usually glabrous	NC, CC, SC, NT, CT, NWS, CWS, NWP , SWP, SFWP	Usually grows in woodland on good soil	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
		perennial, to 1 m high				
<i>Chrysocephalum apiculatum</i>	Herb	Perennial herb	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Grows in various communities and soil types, usually on open or disturbed sites; widespread	RG1, N24, N23, N20, BGW1, BGW2,	Yes
<i>Cymbopogon refractus</i>	Grass	Caespitose perennial	NC, CC, SC, NT, CT, ST, NWS, CWS, NWP , SWP, NFWP	Widespread on poor soils	RG1, N24, N20, BGW1, N13, 50, 75, 89, 31, 34	Yes
<i>Dianella longifolia</i>	Herb	Perennial herb	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP	Common in sclerophyll forest; widespread	RG1	Yes
<i>Dianella revoluta</i>	Herb	Perennial herb	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, SFWP	Grows in sclerophyll forest, woodland and mallee; widespread	RG1, BGW1, N13, 50, 75, 89, 94, 34	Yes
<i>Dichanthium sericeum</i>	Grass	Erect perennial, flowers mostly summer	NC, CC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread, often on self-mulching clays	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Dichelachne micrantha</i>	Grass	Tufted perennial, flowers spring- summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, LHI	Common, in dry or wet sclerophyll forest	No	Yes
<i>Dichelachne sciurea</i>	Grass	Unknown	Unknown	Unknown	No	No
<i>Diuris dendrobioides</i>	Orchid	Terrestrial herb, flowers Sep - Jan	NC, NT, CT, ST, NWS, CWS, SWP	Grows in grassy sclerophyll forest and grassland, widespread	No, not in range	No
<i>Dodonaea viscosa</i>	Shrub or tree	Spreading erect shrub or tree to 8 m high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP, LHI	Many subspecies grown in many different habitats	(subsp. <i>mucronata</i>), 50	Yes
<i>Echinopogon caespitosus</i>	Grass	Loosely or densely tufted perennial	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS	Grows in forest or grassland, often in disturbed areas	50	No
<i>Ehretia membranifolia</i>	Shrub or tree	Tall shrub or small tree 1 -12 m high	NWS, NWP	Grows in dry rainforest or scrubs, or woodland on rocky outcrops; north from Gunnedah district	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Elymus scaber</i>	Grass	Loosely tufted perennial, flowers mainly late winter to spring	NC, CC, SC, NT, CT, ST (records in NWP)	Coast and tablelands; also Vic, Tas, SA and WA	No	No
<i>Eremophila mitchellii</i>	Shrub or tree	Shrub or small tree to 10 m high	NWS, CWS, NWP , SWP, NFWP, SFWP	Usually grows in a variety of vegetation communities on sandy loam and clay loam soils; north from Hillston and west to White Cliffs	No	No
<i>Eucalyptus albens</i>	Tree	Tree to 25 m high	CC, NT, CT, ST, NWS, CWS, SWS, NWP	Widespread, community dominant, in grassy or sclerophyll woodland on a range of soils, usually of higher fertility; chiefly on Western Slopes	No	No
<i>Eucalyptus blakelyi</i>	Tree	Tree to 20 m high	NT, CT, ST, NWS, CWS, SWS, NWP	Widespread and abundant, in grassy woodlands on various usually	RG1, N24, N23, N22, N20, BGW1,	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				moderately fertile soils	N13, 50, 57, 75, 89, 20, 25, 31, 34	
<i>Eucalyptus bridgesiana</i>	Tree	Tree to 20 m high	NC, NT, CT, ST, NWS, CWS, SWS	Widespread and frequent, in grassy woodland on drier sites, often shallower soils on slopes	No	No
<i>Eucalyptus conica</i>	Tree	Tree to 20 m high	NC, NT, ?CT, NWS, CWS, SWS, NWP , SWP	Locally frequent, in grassy or sclerophyll woodland on light loamy soils of medium fertility; north from Wagga.	BGW2	Yes
<i>Eucalyptus goniocalyx</i>	Tree	Tree to 15 m high	NT, CT, ST, NWS, CWS, SWS	Widespread and abundant in open grassy or sclerophyll woodland on dry shallow soils on sloping sites; south from the Liverpool Ra	No, not in range	No
<i>Eucalyptus melliodora</i>	Tree	Tree to 30 m high	NC, CC, SC, NT, CT, ST, NWS,	Widespread and locally frequent, in	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
			CWS, SWS, NWP , SWP	grassy woodland on moderately fertile often sandy or alluvial so		
<i>Eucalyptus microcarpa</i>	Tree	Tree to 25 m high	CC, CT, NWS, CWS, SWS, NWP , SWP	Widespread and locally abundant, in grassy woodland on loamy soils of moderate fertility; west from Mudgee	No	No
<i>Eucalyptus nortonii</i>	Tree	Tree to 15 m high	NT, CT, ST, NWS, CWS, SWS	Widespread and locally frequent, in open woodland on dry shallow soils on rocky sites; south from near Manilla	No, not in range	No
<i>Eulalia aurea</i>	Grass	Erect perennial, flowers most of the year	NT, NWS, CWS, SWS, NWP , SWP, NFWP	Widespread but often in ephemeral water courses in drier areas	No	Yes
<i>Exocarpos cupressiformis</i>	Shrub or small tree	Shrub or small tree to 8 m high	NC, CC, SC, NT, CT, ST, NWS,	Widespread in a variety of habitats and soils	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
			CWS, SWS, NWP , SWP			
<i>Geijera parviflora</i>	Shrub or tree	Shrub or small tree to 10 m high	NC, NWS, CWS, NWP , SWP, NFWP, SFWP	Grows in inland regions in mixed woodland communities; widespread in western districts, except for the far northwest, infrequent in the south	No	No
<i>Geranium solanderi</i>	Herb	Perennial herb, flowers throughout year but chiefly Aug.–Dec	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Widespread in woodland and grassland	No	No
<i>Glycine clandestina</i>	Non-stoloniferous twiner	Flowers all year	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP	Widespread from coast to subalpine situations	BGW1, 89, 20, 34, 50, (Glycine sp.) - N23, 57,	Yes
<i>Glycine tabacina</i>	Stoloniferous scrambler	Flowers mainly spring–autumn	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Common amongst grasses in open situations, also in woodland	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Glycine tomentella</i>	Non-stoloniferous twiner	Flowers Nov - Mar	NC, NWS, CWS, NWP , NFWP	Grows in a variety of habitats, from woodland to littoral rainforest, riverine floodplains or inland spinifex communities	No	No
<i>Gonocarpus elatus</i>	Herb or sub-shrub	Perennial herb or sub-shrub	SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread in open situations	No	No
<i>Goodenia pinnatifida</i>	Herb	Decumbent or ascending herb	NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Grows in a variety of communities; widespread in inland districts, west from Armidale area	No	No
<i>Hibbertia linearis</i>	Shrub	Erect or diffuse shrub, flowers mainly spring to summer	NC, CC, SC, NT, CT, CWS	Widespread in heath and dry sclerophyll forest on sands; north from the Vic. border. This taxon is extremely variable	No, not in range	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Hibbertia obtusifolia</i>	Shrub	Erect or diffuse shrub, flowers spring to summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	This is an extremely variable species. Some specimens from Point Perpendicular have leaves sparsely covered with crinkly hairs. Widespread on sandy or gravelly soils	50	Yes
<i>Hypericum gramineum</i>	Herb	Erect herb, flowers spring to early summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , NFWP	Grows in well-drained soils of open forest and grassland	No	Yes
<i>Jacksonia scoparia</i>	Shrub or tree	Shrub or small tree up to 12 m high	NC, CC, SC, NT, CT, ST, NWS, CWS, NWP , SWP	Widespread on low-nutrient gravelly soils associated with shales or clay, on hillsides and ridges; north from the Bega district	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Jasminum lineare</i>	Tangled shrub	Prostrate or scrambling shrub, flowers throughout the year	NWS, CWS, NWP , SWP, NFWP, SFWP	Grows in woodland, scrub or vine thickets, often among boulders; widespread in inland districts, west from the Tamworth and Murrurundi districts	No	Yes
<i>Jasminum suavissimum</i>	Subshrub, scrambler or twiner	Subshrub to 0.5 m high or trailing scrambler or twiner, flowers spring to summer	NC, NT, NWS, NWP	Widespread, grows in sclerophyll forest and woodland; in inland districts north from Quirindi area, and in drier coastal ranges, chiefly north of the Clarence R., but also recorded from the Hunter Valley.	No	Yes
<i>Leptorhynchos squamatus</i>	Herb	Erect or ascending herb, flowers summer to autumn	NC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Usually at higher altitudes, in open areas or in low-growing grassland; south from Glen Innes district	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Lissanthe strigosa</i>	Shrub	Shrub 15 - 70 cm high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP	Grows in dry sclerophyll forest, dry scrub and heath on sandy soils; widespread, west to Pilliga.	BGW1, 50, 89, 94	Yes
<i>Lomandra filiformis</i>	Herb	Perennial tussock, flowers chiefly Oct - Nov	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in dry sclerophyll forest usually on well-drained often sandy or rocky soils	No	Yes
<i>Melichrus urceolatus</i>	Shrub	Erect shrub 20 - 150 cm high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in dry sclerophyll forest, Callitris woodland and Acacia scrub on skeletal, sandy or loamy soils; widespread. All divisions except NFWP & SFWP; Qld, Vic	N20, BGW1, 50, 75, 89, 94, 25, 31, 34	Yes
<i>Microseris lanceolata</i>	Herb	Perennial herb, flowers spring-summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, SFWP	Widespread	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Notelaea microcarpa</i>	Tree	Crooked tree to 10 m high	NC, NT, ST, NWS, CWS, NWP	Grows in dry sclerophyll woodland and smaller patches of gully rainforest north from the Hunter valley	No	No
<i>Olearia elliptica</i>	Shrub	Shrub to 2 m high	NC, CC, NT, CT, ST, NWS, CWS, NWP , LHI	Grows in heath, woodland and sclerophyll forest in sandy or dark silty soils in mountainous terrain; widespread, north from Berry	No	No
<i>Olearia viscidula</i>	Shrub	Shrub to 2.5 m high	NC, CC, SC, NT, CT, ST, NWS, CWS	Grows in dry sclerophyll forest and eucalypt woodland; south from the Nandewar Ra	No, not in range	No
<i>Oxalis perennans</i>	Herb	Herb with taproot, flowers May - Dec	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP ,	Widespread, more common inland and commonly on	57	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
			SWP, NFWP, SFWP	heavy-textured soils		
<i>Pandorea pandorana</i>	Scrambler or climber	Woody scrambler or climber	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, SFWP, LHI	Grows to a large woody climber in coastal rainforest or as a scrambler or climber in moist gullies in sclerophyll forest and woodland, frequently in rocky sites	No	No
<i>Panicum queenslandicum</i>	Grass	Densely caespitose perennial, flowers summer	NC, NT, NWS, CWS, SWS, NWP , SWP	Grows in floodways in drier country	No	No
<i>Parsonsia eucalyptophylla</i>	Climber	Tall woody climber	NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread in woodland and scrub in inland areas; north from Mildura district and Narrandera and east to the upper Hunter Valley	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Pimelea curviflora</i>	Subshrub or shrub	Subshrub or shrub 20 - 150 cm high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP		No	No
<i>Plantago debilis</i>	Herb	Perennial or annual	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP	Grows mostly in moist forest on basaltic- and metamorphic- derived soils; widespread, from coastal districts to inland areas	No	Yes
<i>Plantago gaudichaudii</i>	Herb	Perennial, flowers mostly Sept - April	NC, CC, SC, NT, CT, ST, CWS, SWS, SWP	Grows in grassland, forest and woodland, often on heavy soil; widespread, from subcoastal districts to the Hay-Deniliquin area	No, not in range	No
<i>Poa labillardieri</i>	Grass	Perennial, flowers most of the year	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows on river flats and moist situations, and in forests, extending up open sheltered slopes.	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Poa sieberiana</i>	Grass	Perennial, flowers most of the year	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	A variable grass of wide distribution and growing in many habitats	No	No
<i>Rostellularia adscendens</i>	Herb	Scending herb, flowers throughout the year	NC, NT, NWS, CWS, NWP , SWP, NFWP	Grows chiefly in woodland, often along watercourses or in rocky sites; north from Henty	No	No
<i>Rumex brownii</i>	Herb	Perennial 50-80 cm high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, SFWP, *LHI	Weed of lawns and pastures.	BGW2, 57, 20	Yes
<i>Sida corrugata</i>	Herb	Prostrate to decumbent herb	NC, CC, NT, CT, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Grows on clay and sandy soils	No	No
<i>Sorghum leiocladum</i>	Grass	Tufted perennial, flowers in summer	NC, CC, SC, NT, CT, ST, NWS, CWS	In woodland on poorer soils	No, not in range	No
<i>Stackhousia monogyna</i>	Herb	Perennial to 70 sm high, flowers late winter to early summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Grows in heath, grassland, woodland and sclerophyll forest,	No	No

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
				rarely in swamps; widespread. All districts except NFWP & SFWP; Qld, Vic., Tas., S.A., W.A		
<i>Stackhousia viminea</i>	Herb	Perennial to 70 cm high, flowers spring to autumn	NC, CC, SC, NT, CT, ST, NWS, CWS, NWP	Grows in forest and woodland, usually in shallow soil amongst rocks, occasionally in swampy locations; widespread on the coast and ranges, inland to Tamworth district	No	No
<i>Swainsona galegifolia</i>	Herb	Perennial to 1 m high	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP	Widespread in a variety of habitats	N22 (<i>Swainsona</i> sp.), 57	Yes
<i>Templetonia stenophylla</i>	Shrub	Small shrub less than 50 cm high, flowers spring	NT, CT, NWS, CWS, SWS, NWP	Widespread, mostly in dry sclerophyll forest, often on river banks	No	Yes

Species	Form	Notes	Botanical division (Harden 1990)	Distribution	Present in subject plots	Present in other Narrabri Gas Project plots
<i>Themeda australis</i>	Grass	Caespitose perennial, flowers mostly spring to summer	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread in a variety of habitats	No	Yes
<i>Wahlenbergia communis</i>	Herb	Perennial tufted herb, flowers throughout the year	NC, CC, SC, NT, CT, ST, NWS, CWS, SWS, NWP , SWP, NFWP, SFWP	Widespread in open disturbed sites, particularly along roadsides	BGW1, 50, (<i>Wahlenbergia</i> sp) - RG1, N23, 57, 31, 34	Yes

Appendix C: Sample site photos



Plate 1: Plot 20



Plate 2: Plot 25



Plate 3: Plot 31



Plate 4: Plot 34



Plate 5: Plot 50



Plate 6: Plot 57



Plate 7: Plot 75



Plate 8: Plot 89



Plate 9: BGW1



Plate 10: BGW2



Plate 11: RG1



Plate 12: N20



Plate 13: N22



Plate 14: N23



Plate 15: N24

eco
logical
AUSTRALIA



HEAD OFFICE

Suite 4, Level 1
2-4 Merton Street
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

CANBERRA

Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

COFFS HARBOUR

35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

PERTH

Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

DARWIN

16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601

SYDNEY

Level 6
299 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9264 0717

NEWCASTLE

Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

ARMIDALE

92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

WOLLONGONG

Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

BRISBANE

51 Amelia Street
Fortitude Valley QLD 4006
T 07 3503 7193

ST GEORGES BASIN

8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

NAROOMA

5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

MUDGEES

Unit 1, Level 1
79 Market Street
Mudgee NSW 2850
T 02 4302 1230
F 02 6372 9230

GOSFORD

Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897

1300 646 131

www.ecoaus.com.au



Appendix F

Draft biodiversity offset strategy

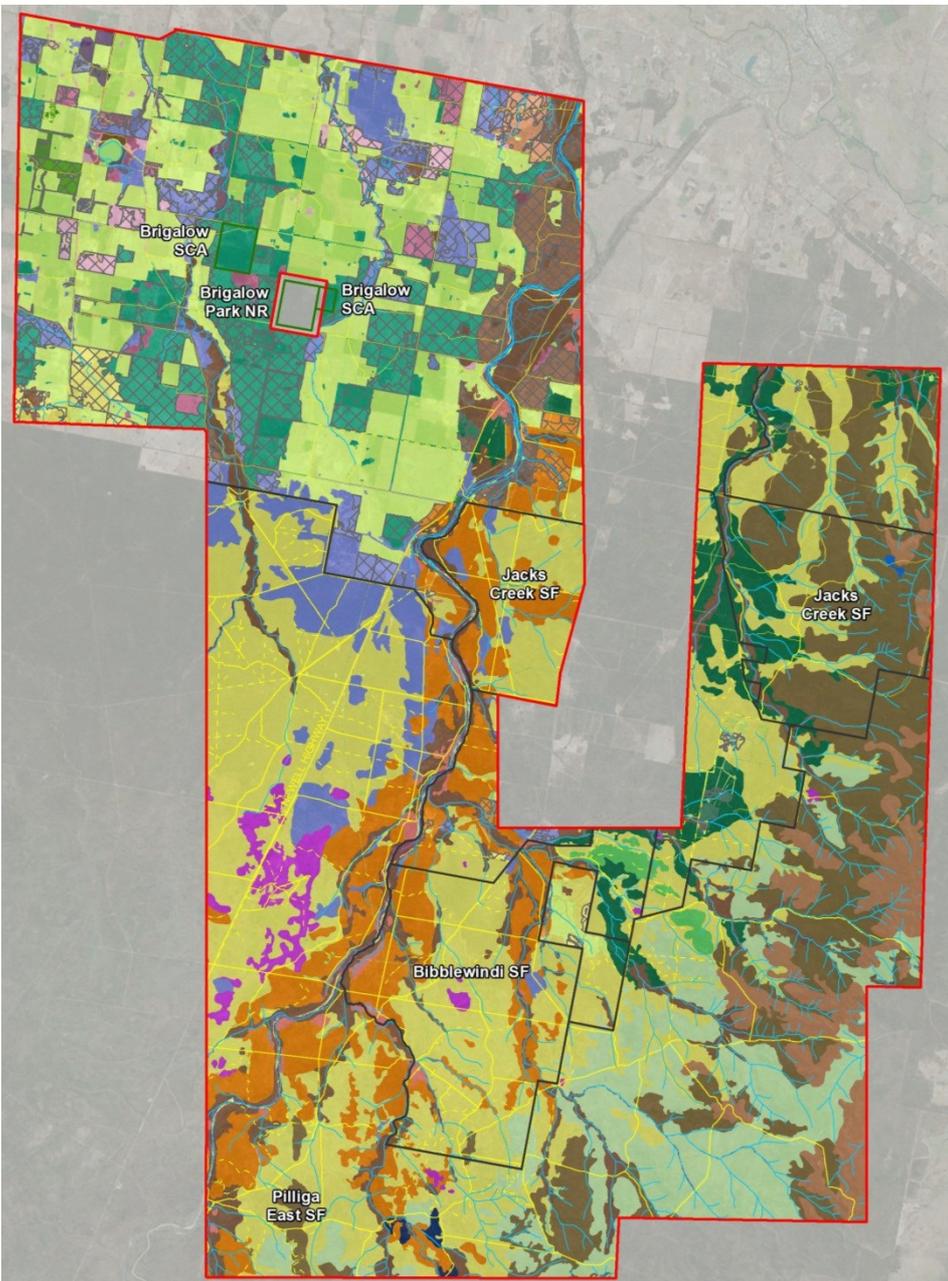


Narrabri Gas Project

Working Draft: Biodiversity Offset Strategy

Prepared for
Santos NSW (Eastern) Pty Ltd

March 2018



This report should be cited as 'Eco Logical Australia 2018. *Narrabri Gas Project Biodiversity Offset Strategy*. Prepared for Santos NSW (Eastern) Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Santos NSW (Eastern) Pty Ltd.

Disclaimer

This document may only be used for the purpose for which it was commissioned and in accordance with the contract between Eco Logical Australia Pty Ltd and Santos NSW (Eastern) Pty Ltd. The scope of services was defined in consultation with Santos NSW (Eastern) Pty Ltd., and the availability of reports and other data on the subject area. Changes to available information, legislation and schedules are made on an ongoing basis and readers should obtain up to date information.

Eco Logical Australia Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report and its supporting material by any third party. Information provided is not intended to be a substitute for site specific assessment or legal advice in relation to any matter. Unauthorised use of this report in any form is prohibited.

Template 08/05/2014

Contents

1	Introduction	1
1.1	Secretary’s environmental assessment requirements	1
1.2	Objectives	1
1.3	Report structure	2
2	Biodiversity Offset Strategy	1
2.1	Offset principles	1
2.2	Offset approach	2
2.3	Offset requirements to achieve long-term conservation outcomes	3
2.3.1	Assessment using the Major Projects Credit Calculator	3
2.3.2	Rehabilitation credits	9
2.3.3	Ecosystem credits	11
2.3.4	Species credits	5
2.3.5	Hollow-bearing trees.....	8
2.3.6	Assumptions and limitations	8
2.4	EPBC offset requirements	8
2.5	Cultural Heritage.....	10
2.5.1	Cultural heritage offsets.....	10
2.5.2	Community access to cultural heritage offsets.....	10
2.5.3	Community management of offset lands	10
3	Biodiversity offset package	11
3.1	Land based offset sites.....	11
3.1.1	Biobanking public register and expression of interest	12
3.1.2	Liaison with OEH and Narrabri Council	12
3.1.3	Analysis of freehold land in the Pilliga and Pilliga Outwash IBRA subregions.....	12
3.1.4	Properties for sale in the region	15
3.1.5	Feasibility of offsets	18
3.2	Supplementary measures.....	18
3.2.1	Species threat analysis.....	19
3.2.2	Management costs	26
3.2.3	Nil-tenure feral animal control strategy.....	34
3.2.4	Compensatory measures	34
3.3	Indigenous cultural heritage values and activities	35
3.4	Biodiversity Conservation Fund or bond	35
4	Statement of commitments	36
	References	37

Appendix A Culturally important food plants	43
Appendix B Threats and management actions	56
Appendix C Koala Research Proposal	69
Appendix D Supplementary Biometric Plot Data	70

List of figures

Figure 1: Study area	1
Figure 2: Infrastructure 'carried forward'	13

List of tables

Table 1: Species requiring survey and survey time matrix	6
Table 2: 'Species credit' species assessed	8
Table 3: 'Species credit' species likely to respond positively to disturbance and rehabilitation	10
Table 4: Major Projects Assessment (Version 4.1) – Ecosystem Credits Required	1
Table 5: Major Projects Assessment (Version 4.1) – Flora Species Credits Required.....	6
Table 6: Major Projects Assessment (Version 4.1) – Fauna Species Credits Required.....	7
Table 7: Biobank site expressions of interest.....	12
Table 8: Potential offsets available on freehold land in the study area	13
Table 9: Type and quantum of PCTs present on properties for sale	16
Table 10: Threatening processes – fauna.....	20
Table 11: Threatening processes – flora.....	22
Table 12: Weed species of most concern	24
Table 13: Costs for fox baiting programs in various areas of Australia (adjusted to 2014 prices).....	27
Table 14: Comparative costs of feral pig control methods in different habitats	29
Table 15: Comparative costs of feral goat control methods in different habitats (adjusted to 2014 prices)	30
Table 16: Rabbit control options (adjusted to 2014 prices).....	31

Table 17: Approximate costs per hectare for the control of weeds of concern to threatened species occurring in study area32

Table 18: Costs of prescribed burning in Australia33

Table 19: Threats to threatened fauna species known or with the potential to occur in the study area ..57

Table 20: Management actions that benefit threatened fauna species known or with the potential to occur in the study area62

Table 21: Threats to threatened flora species known or with the potential to occur in the study area66

Table 22: Management actions that benefit threatened flora species known or with the potential to occur in the study area67

Abbreviations

Abbreviation	Description
BBAM	Biobanking Assessment Methodology
BBCC	BioBanking Credit Calculator
BC Act	NSW <i>Biodiversity Conservation Act 2016</i>
BOS	Biodiversity Offset Strategy
BVT	Biometric Vegetation Type
CCA	Community Conservation Area
CHMP	Cultural Heritage Management Plan
CMA	Catchment Management Authority
CQCHM	Central Queensland Cultural Heritage Management
DNG	Derived Native Grassland
DoE	Commonwealth Department of Environment
DPE	NSW Department of Planning and Environment
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EPA Act	NSW <i>Environmental Planning and Assessment Act 1979</i>
EPBC Act	Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>
FBA	Framework for Biodiversity Assessment
IBRA	Interim Biogeographic Regionalisation for Australia
IUCN	International Union for Conservation of Nature
LALC	Local Aboriginal Land Council
MNES	Matters of National Environmental Significance
NPW Act	NSW <i>National Parks and Wildlife Act 1974</i>
NPWS	NSW National Parks and Wildlife Service
NSW	New South Wales
NT	Native Title
OEH	NSW Office of Environment and Heritage
PA	Planning Agreement
PCT	Plant Community Type
RVC	Regional Vegetation Class
SEARs	Secretary's Environmental Assessment Requirements
TBD	To be determined
BC Act	Former NSW <i>Threatened Species Conservation Act 1995</i>

1 Introduction

Eco Logical Australia (ELA) was commissioned by the Proponent to prepare a Biodiversity Offset Strategy for the Narrabri Gas Project (the project). The Biodiversity Offset Strategy forms part of the Environmental Impact Statement (EIS) which supports the Proponents' application for development consent for the project (GHD, 2015).

The Biodiversity Offset Strategy provides a comprehensive strategy for residual impacts of the project following implementation of avoidance, minimisation and mitigation strategies which are detailed in the Ecological Impact Assessment (ELA, 2015) which supports the Environmental Impact Statement. The Biodiversity Offset Strategy is a framework document which will be supported by a detailed Biodiversity Offset Management Plan detailing how the offset strategy and offset package will be implemented. Subject to approval of the project, the Biodiversity Offset Management Plan will be prepared and implemented before the commencement of the project.

The study area for the project is shown in **Figure 1**.

1.1 Secretary's environmental assessment requirements

The Secretary's Environmental Assessment Requirements (SEARs) for the project identify the following key issues relating to biodiversity offsets:

'a strategy to offset any residual impacts of the development in accordance with the NSW Biodiversity Offsets Policy for Major Projects, unless otherwise agreed by OEH'

It is important to note the NSW Biodiversity Offsets Policy for Major Projects and the Framework for Biodiversity Assessment (FBA) are both in a transitional implementation period. During the transitional implementation period, the NSW Biodiversity Offsets Policy for Major Projects states that:

'... if application of the policy or its underlying tool, the Framework for Biodiversity Assessment (FBA), results in perverse outcomes that do not reflect the intentions of the policy, the consent authority may vary the application of the policy or FBA to address this'

This report details how these requirements will be fulfilled.

1.2 Objectives

The key objectives of the Biodiversity Offset Strategy are to:

- Provide a comprehensive strategy to ensure that the residual impacts of the project are adequately compensated for and that long-term conservation outcomes are achieved, by ensuring:
 - Vegetation, habitat and threatened species at offset sites have equal or greater conservation status to areas impacted by the project.
 - Offsets are greater than the loss of areas impacted by the project.
 - Land-based offset sites, supplementary measures and contributions to the Biodiversity Conservation Fund are appropriately funded, secured and managed.
- Ensure that Aboriginal people have opportunities to increase cultural knowledge of their country and opportunities to access and manage its natural and cultural values.

1.3 Report structure

The report is structured as follows:

1. **Introduction** - introduces the report, objectives and report structure
2. **Biodiversity Offset Strategy** – outlines how non-avoidable impacts to native vegetation and threatened species and their habitat will be quantified and the approach that will be taken achieved long-term conservation outcomes.
3. **Biodiversity Offset Package** – details a package of measures that compensate for non-avoidable impacts to native vegetation and threatened species and their habitat.
4. **Statement of commitments** – outlines the Proponents' commitment to the identification, securing and conservation of biodiversity and cultural heritage values as part of the project.

Figure 1: Study area

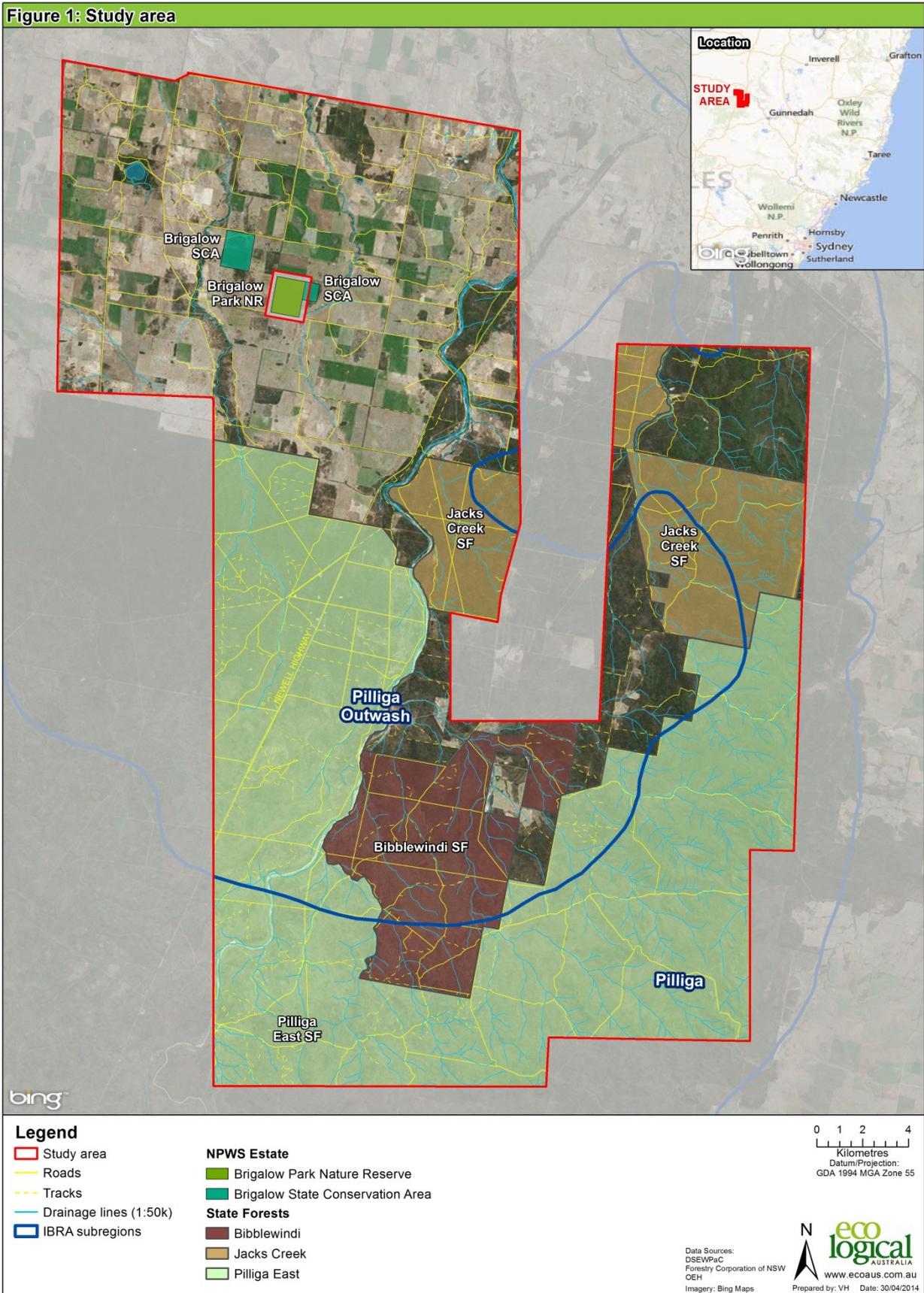


Figure 1: Study area

2 Biodiversity Offset Strategy

This Biodiversity Offset Strategy has been prepared to ensure that the residual impacts of the project are adequately compensated for and that long-term conservation outcomes are achieved in recognition of the *NSW Offsetting Principles* (OEH, 2014b) and the *NSW Biodiversity Offset Policy for Major Projects* (OEH, 2014a). This Biodiversity Offset Strategy considers threatened and migratory species, populations and ecological communities listed under the *NSW Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The EPBC Act Offset Policy requires 'offset measures to be considered for residual impacts that cannot be mitigated to ensure the protection of Matters of National Environmental Significance (MNES) in perpetuity'. This Biodiversity Offset Strategy has been prepared to generally be consistent with the EPBC Act Offset guide (DSEWPaC, 2012). As the *NSW Biodiversity Offset Policy for Major Projects* was developed as a whole-of-government policy and includes MNES, offsets determined under the *NSW Biodiversity Offset Policy for Major Projects* are considered to satisfy EPBC offset requirements.

The Biodiversity Offset Strategy provides a quantification of the impacts of the project informed by the Framework for Biodiversity Assessment to guide the development of the offset strategy and is based on direct impacts of 988.8 ha (of which 586.6 ha will be rehabilitated following construction), an indirect impact of 181.1 ha and cumulative impacts of 84.8 ha (ELA, 2015).

Methods undertaken to quantify the potential impacts of the project are outlined in Section 4 of the Ecological Impact Assessment of the project (ELA, 2015) and are not repeated here. Similarly, measures taken to avoid, minimise and mitigate the impacts of the project are outlined in Section 7 and Section 8 of the Ecological Impact Assessment (ELA, 2015).

A Biodiversity Offset Package (**Section 3**) has been prepared to provide a framework for accounting for offset liability through land-based offset properties, supplementary measures, research and contribution to the Biodiversity Conservation Fund (once established).

2.1 Offset principles

The following principles for providing offsets against the impacts of the project have been used to guide the development of the Biodiversity Offset Strategy:

NSW Biodiversity Offset Policy for Major Projects

1. Before offsets are considered, impacts must first be avoided and unavoidable impacts minimised through mitigation measures. Only then should offsets be considered for the remaining impacts.
2. Offset requirements should be based on a reliable and transparent assessment of losses and gains.
3. Offsets must be targeted to the biodiversity values being lost or to higher conservation priorities.
4. Offsets must be additional to other legal requirements.
5. Offsets must be enduring, enforceable and auditable.
6. Supplementary measures can be used in lieu of offsets.

Commonwealth

1. Deliver an overall conservation outcome that improves or maintains the viability of the aspect of the environment that is protected by national environment law and affected by the proposed action.
2. Be built around direct offsets but may include other compensatory measures.
3. Be in proportion to the level of statutory protection that applies to the protected matter.
4. Be of a size and scale proportionate to the residual impacts on the protected matter.
5. Effectively account for and manage the risks of the offset not succeeding.
6. Be additional to what is already required, determined by law or planning regulations or agreed to under other schemes or programs (this does not preclude the recognition of state or territory offsets that may be suitable as offsets under the EPBC Act for the same action).
7. Be efficient, effective, timely, transparent, scientifically robust and reasonable.
8. Have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.

In assessing the suitability of an offset, government decision-making will be:

1. Informed by scientifically robust information and incorporate the precautionary principle in the absence of scientific certainty.
2. Conducted in a consistent and transparent manner.

The Commonwealth policy identifies two kinds of biodiversity offset, 'direct offsets' including such measures as long-term protection of existing habitat (land-based offsets and supplementary measures) and 'compensatory measures' (indirect offsets) for such measures as implementing recovery plan actions or contributions to relevant research.

As previously noted, offsets determined under the NSW Biodiversity Offset Policy for Major Projects are considered likely to satisfy EPBC offset requirements.

2.2 Offset approach

The Biodiversity Offset Strategy follows a four-step approach:

1. Quantification of the impacts of the project informed by the Framework for Biodiversity Assessment (FBA) to guide the development of the offset strategy including direct, indirect and cumulative impacts as well as the contribution that undertaking immediate rehabilitation post construction makes to reducing the overall offset liability.
2. Undertaking 'reasonable steps' to locate like-for-like offset, including:
 - a. Checking the biobanking public register and having an expression of interest (EOI) for credits wanted for at least six months.
 - b. Liaising with the NSW Office of Environment and Heritage (OEH) and Narrabri Council to obtain a list of potential sites that meet the requirements for offsetting.
 - c. Considering properties for sale in the area.
 - d. providing evidence of why offset sites are not feasible.
3. Development and contribution of funds for supplementary measures such as feral animal control, threatened species research and monitoring measures to be implemented through Planning Agreements (PAs).
4. For the remaining offset liability to be held for eventual transfer into the Biodiversity Conservation Fund (once operational).

2.3 Offset requirements to achieve long-term conservation outcomes

The project will result in the removal of up to 988.8 ha of remnant native vegetation and fauna habitat including 0.1 ha of Weeping Myall Woodlands (TSC & EPBC Act Endangered), 19.3 ha of Brigalow (*Acacia harpophylla* dominant and co-dominant) (TSC & EPBC Act Endangered) and 5.9 ha of Fuzzy Box Woodland (TSC Endangered), habitat for at least 26 threatened fauna species, six migratory birds and ten threatened plant species.

As required by the Framework for Biodiversity Assessment, the direct impacts of the project were assessed by an accredited Biobank Assessor using the Major Projects Credit Calculator Version 4.0 and submitted to OEHL for approval. The assessment was split into three equal parts to manage known capacity issues with the Major Projects Credit Calculator. The outputs of the direct impact credit calculation (in terms of credits required per hectare of impact) were then used to determine the total quantum of biodiversity offsets required for the project (including direct, indirect and cumulative impacts).

Four key elements were considered:

- **Direct impacts** – 988.8 ha - vegetation/habitat/species clearance.
- **Indirect impacts** – 181.1 ha - fragmentation, noise, light, weeds, feral animals etc.
- **Cumulative impacts** – 84.8 ha - existing impacts in the study area from infrastructure that will be 'carried forward' by the project that have not yet been offset.
- **Immediate rehabilitation** – 586.6 ha - partial rehabilitation of linear and non-linear infrastructure areas immediately following construction.

Specific detail on how these figures were determined are contained within the Ecological Impact Assessment (ELA, 2015), with further detail provided in **Section 2.3.1** and **Section 2.3.2**.

2.3.1 Assessment using the Major Projects Credit Calculator

The process for undertaking an assessment using the Framework for Biodiversity Assessment and the Major Projects Credit Calculator involves eight steps:

- Step 1 – Compile data
- Step 2 – Landscape value assessment
- Step 3 – Enter vegetation zones
- Step 4 – Geographic / habitat features
- Step 5 – Site survey
- Step 6 – Site values and management scores
- Step 7 – Threatened species survey results
- Step 8 – Credits

These steps and the process followed to assess the offset requirements of the project using the Major Projects Credit Calculator are detailed below.

Step 1 – Compile data

Comprehensive baseline data and mapping products collected and developed over four years including 1:10,000 scale Plant Community Type (PCT) vegetation and fauna habitat mapping, threatened flora survey and modelling and 336 full floristic biometric plots (ELA, 2015).

A total of 22 Plant Community Types have been mapped within the study area, however only 19 of these are likely to be directly, indirectly or cumulatively impacted on by the project. In addition 13 derived native grassland (DNG) forms are considered likely to be directly, indirectly or cumulatively impacted. Plant

Community Types and their associated 2014 Biometric Vegetation Types (BVTs) were compiled for the assessment.

Biometric data from 336 full floristic biometric plots (including quantitative data for native species richness, vegetative cover in each structural layer, weed abundance, regeneration occurring, and fauna habitat features such as length of logs and presence of hollows) were compiled for the assessment.

In the published Environmental Impact Statement, there is a shortage of nine vegetation plots (five in derived native grassland, four in native vegetation) required to meet the minimum requirements of the Framework for Biodiversity Assessment. It should be noted however, that for many vegetation zones (more than 70%), the minimum number of plots has far exceeded the requirements of the FBA (in total 245 additional plots). These additional nine plots have now been completed and have been utilised in determining the direct impact credit liability for the project. The supplementary Biometric plot data for the additional plots is included in **Appendix D**.

Threatened flora and fauna species identified within the study area which are also classified as 'species credit' species under the Framework for Biodiversity Assessment were also compiled. This list includes nine threatened flora species and six threatened fauna species.

Step 2 – Linear/multiple fragmentation impacts module

An assessment of the potential impacts of the project at the landscape scale was undertaken using the linear/multiple fragmentation impacts module of the Major Projects Credit Calculator. This module requires the assessment of four key attributes including percent cover of native vegetation, connectivity, patch size and change in perimeter to area ratio. These attributes were assessed as follows:

1. Native vegetation cover before and after development
 - Based on detailed vegetation mapping undertaken for the project, the total native vegetation cover before development in the study area was 84.6%. As the project will only result in the removal of 1.29% of native vegetation within the study area, the total vegetation cover after development is 83.3% which results in a score of '0' for this attribute (i.e. no change).
2. Assess connectivity value
 - The project is likely to impact on the riparian buffer of a sixth order stream or greater (state significant biodiversity link), which results in a score of 12.5 for this attribute.
3. Assess patch size by Mitchell Landscape
 - The study area contains extra-large patch size classes for at least one of the Mitchell Landscapes that have been mapped in the study area, which results in a score of 12.5 for this attribute.
4. Assessing the change in area to perimeter ratio
 - As the project includes a combination of known and modelled impacts, it is not possible to assess the change in area to perimeter ratio as a result of the project. As such, a precautionary approach has been undertaken and the highest possible score of 10 was selected by the assessor by entering an Area/Perimeter ratio before development of '100' and an Area/Perimeter ratio after development of '0'.
 - Note that this represents the worst case as there is an existing network of over 760 km of roads within the forested portion of the study area which already contribute to existing fragmentation. Furthermore, this assessment does not take into consideration design measures proposed to avoid and minimise impacts such as the co-location of linear infrastructure such as gas and water gathering systems and access tracks with existing roads, access tracks and disturbance corridors wherever possible.

The intent of the linear/multiple fragmentation impacts module is to more accurately assess the potential impacts of a project (such as a coal seam gas development) at a landscape scale. This has been achieved through the reapportioning of landscape value weightings from 'site based developments' and the additional requirement to assess change in area to perimeter ratio for linear/multiple fragmentation impacts developments. The purpose of assessing change in area to perimeter ratio is to account for additional indirect impacts of a development such as fragmentation and edge effects at the landscape scale.

It is important to note that the Framework for Biodiversity Assessment does not differentiate between the width of fragments (e.g. a 1 m wide linear clearing is treated the same as a 100 m wide linear clearing). Under the BioBanking assessment methodology (DECC, 2008a), patches of woody habitat are considered to be linked if they are separated by less than 100 m (or less than 30 m for grassy ecosystems), provided the habitat is in moderate to good condition, the patch size is greater than 1 ha and the separation is not a dual carriageway or wider highway. The effect that the width and size of fragments will depend on the particular ecological values being considered (e.g. flora, fauna or ecological communities).

The Ecological Impact Assessment (ELA, 2015) considered the impact of fragmentation on each threatened species and ecological community known, or considered potentially to occur in the study area. Assessing the ability of each flora species and ecological community to continue their life cycles and of each fauna species to move through the habitat with the additional fragmentation required understanding of the dispersal potential of each species and the magnitude of the clearing in comparison to this dispersal potential.

The Ecological Impact Assessment (ELA, 2015) has demonstrated that the impacts of the project (including fragmentation and edge effects) are unlikely to significantly impact threatened species or ecological communities. This is primarily due to the small proportion of habitat being removed relative to that retained in the study area; the removal of habitat not being at a scale likely to result in the isolation or fragmentation of populations; that the project is unlikely to result in invasive species or diseases becoming established; and that progressive rehabilitation of disturbed areas will be implemented as part of the project. Therefore, the potential impacts that the project may have at the landscape scale are not considered to be significant. Nevertheless, the linear/multiple fragmentation impacts module has been utilised as required in the Framework for Biodiversity Assessment and has resulted in a conservative assessment.

Step 3 - Enter vegetation zones

Based on the data compiled in Step 1, a total of 31 vegetation zones were entered into the Major Projects Credit Calculator across the following three assessments:

- Narrabri Gas Project 2017 - Part 1 (Proposal ID 0027/2018/4783MP) – 10 vegetation zones and all 'species credit' individuals and habitat
- Narrabri Gas Project 2017 - Part 2 (Proposal ID 0027/2018/4784MP) – 10 vegetation zones
- Narrabri Gas Project 2017 - Part 3 (Proposal ID 0027/2018/4785MP) – 11 vegetation zones

The modelled upper disturbance limit for each Plant Community Type and 'species credit' habitat directly impacted by the project were directly entered into the Major Projects Credit Calculator as required by the Framework for Biodiversity Assessment.

Up to two vegetation zones per Plant Community Type were entered into the tool: Moderate/Good (native vegetation) and Moderate/Good_Derived grassland (derived native grassland). Further stratification of

vegetation was not undertaken as there was little to no variance between site value scores within each of these vegetation zones for each Plant Community Type.

By calculating the direct impact credit liability for Plant Community Types and ‘species credit’ individuals and habitat, the number of credits required per hectare (or per individual for flora species) by the Major Projects Credit Calculator can be determined. The credit per hectare metric can then be readily applied outside of the Major Projects Credit Calculator to obtain the total credit liability of the whole Project. This includes indirect and cumulative impacts for each Plant Community Type and condition combination, even though both indirect and cumulative impacts, and the contribution of rehabilitation measures as part of the offset strategy are not required to be factored into the assessment under the Framework for Biodiversity Assessment.

Due to the requirement for up to two vegetation zones per Plant Community Type (i.e. Moderate/Good and Moderate/Good_Derived grassland), the assessment was split across three assessments in the Major Projects Credit Calculator. For each assessment the Assessment details, Proponent details and Landscape Value required by the Major Projects Credit Calculator were identical. Vegetation zone and site values differed between the three assessments based on the vegetation zones and ‘species credit’ habitat entered into the Major Projects Credit Calculator.

The approach undertaken is consistent with the requirements of the Framework of Biodiversity Assessment. Quantification of the credit liability for indirect and cumulative impacts is not a requirement of the Framework of Biodiversity Assessment and has been undertaken using the credits per hectare metric generated by the Major Projects Credit Calculator for direct impacts.

Step 4 - Geographic / habitat features

Based on the information entered in Steps 1-3, the Major Projects Credit Calculator requires the assessor to answer a series of geographic/habitat feature questions. These questions and their response are detailed below:

- Land within 40 m of watercourses, containing hollow-bearing trees, loose bark and/or fallen timber – YES.
- Land containing within 100 m of riparian woodland on inland rivers containing mature living eucalypts or isolated paddock trees overhanging water or dry watercourses – YES.
- Land containing soil cracks or fallen timber and litter – YES
- On ridges of gilgai clays – YES
- Land within 40 m of riparian woodland on inland watercourses/waterholes containing dead or dying eucalypts – YES
- Wetlands and wet run on areas – YES
- land containing cliffs or rocky areas - YES

Step 5 – Site survey

Based on the information entered in Steps 1-4, the Major Projects Credit Calculator identifies a range of ‘species credit’ species that require survey. A total of 22 species were identified as requiring survey as outlined in **Table 1**. Surveys for these species and a range of other threatened and migratory species were undertaken in the appropriate season and over multiple years.

Table 1: Species requiring survey and survey time matrix

Common name	Scientific name	J	F	M	A	M	J	J	A	S	O	N	D
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Common name	Scientific name	J	F	M	A	M	J	J	A	S	O	N	D
Black-striped Wallaby	<i>Macropus dorsalis</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bluegrass	<i>Dichanthium setosum</i>	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y
<i>Commersonia procumbens</i>	<i>Commersonia procumbens</i>	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y
<i>Cyperus conicus</i>	<i>Cyperus conicus</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eastern Pygmy-possum	<i>Cercartetus nanus</i>	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Five-clawed Worm-skink	<i>Anomalopus mackayi</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Greenhood Orchid	<i>Pterostylis cobarensis</i>	N	N	N	N	N	N	N	N	Y	Y	Y	N
Grey Falcon	<i>Falco hypoleucos</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Koala	<i>Phascolarctos cinereus</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Narrow Goodenia#	<i>Goodenia macbarronii</i>	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y
Native Milkwort	<i>Polygala linariifolia</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pale-headed Snake	<i>Hoplocephalus bitorquatus</i>	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y
Pine Donkey Orchid	<i>Diuris tricolor</i>	N	N	N	N	N	N	N	N	Y	Y	N	N
<i>Prasophyllum</i> sp. Wybong	<i>Prasophyllum</i> sp. Wybong	N	N	N	N	N	N	N	N	N	Y	N	N
Rufous Bettong	<i>Aepyprymnus rufescens</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Slender Darling Pea	<i>Swainsona murrayana</i>	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y
Spiny Peppercross	<i>Lepidium aschersonii</i>	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y
Squirrel Glider	<i>Petaurus norfolcensis</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>Tylophora linearis</i>	<i>Tylophora linearis</i>	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y
Coolabah Bertya	<i>Bertya opponens</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Scant Pomaderris	<i>Pomaderris queenslandica</i>	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Narrow Goodenia is no longer listed as a threatened species

Step 6 - Site values and management scores

This step requires the assessor to enter biometric plot data for each vegetation zone and assign Endangered Ecological Communities where appropriate. Data was compiled into separate comma separated values (CSV) files for each vegetation zone and entered into the Major Projects Credit Calculator.

This step also requires the assessor to assign management zones to each vegetation zone. One management zones was defined for each vegetation zone (complete clearing). The default '0' was applied to site value scores (indicating complete clearing).

The 'Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion' Plant Community Type (PCT 27) could not be assigned to its associated Endangered Ecological Community in the Major Project Credit Calculator. To ensure the correct offset multiplier was assigned to this Plant Community Type, the default Endangered Ecological Community (namely Artesian Springs Ecological Community) was selected.

Due to the size of the study area, some patches of native vegetation may not have had regeneration of overstorey species observed and recorded in the biometric data. Where there was a discrepancy for plots within a native vegetation (i.e. the Moderate/Good zone), overstorey regeneration was updated to '1' (i.e. all species present). Similarly where there was a discrepancy for derived native grassland (Moderate/Good_Derived grassland), the overstorey regeneration score was updated to '0' (i.e. no species present). The net effect of this change is expected to have been minimal.

Step 7 - Threatened species survey results

This step requires the assessor to enter all 'species credit' species likely to be impacted by the development. The assessment of direct impacts to 'species credit' individuals and habitat was undertaken in the first assessment only (Narrabri Gas Project 2017 - Part 1 (Proposal ID 0027/2018/4783MP)).

This includes nine threatened flora and six threatened fauna species (**Table 2**).

Table 2: 'Species credit' species assessed

Common Name	Scientific name
Black-striped Wallaby [#]	<i>Macropus dorsalis</i>
<i>Commersonia procumbens</i>	<i>Commersonia procumbens</i> (syn. <i>Rulingia procumbens</i>)
Coolabah Bertya	<i>Bertya opponens</i>
Eastern Pygmy-possum	<i>Cercartetus nanus</i>
Greenhood Orchid	<i>Pterostylis cobarensis</i>
Koala [#]	<i>Phascolarctos cinereus</i>
Native Milkwort	<i>Polygala linariifolia</i>
Pale-headed Snake	<i>Hoplocephalus bitorquatus</i>
Pine Donkey Orchid	<i>Diuris tricolor</i>
Regent Honeyeater	<i>Anthochaera phrygia</i> [#]
Scant Pomaderris [#]	<i>Pomaderris queenslandica</i>
Spiny Peppercress	<i>Lepidium aschersonii</i>
Squirrel Glider	<i>Petaurus norfolcensis</i>
<i>Tylophora linearis</i> [#]	<i>Tylophora linearis</i>
Winged Peppercress	<i>Lepidium monoplacoides</i>

[#]The threatened species multipliers were updated in Major Project Credit Calculator using the latest up to date information archived from Bionet.

Step 8 – Credits required

This step allows the assessor to generate the 'credits required' for the development. This data was subsequently exported to Microsoft Excel and the direct impact credit requirements for each management zone could be ascertained.

As described above, by calculating the direct impact credit liability for Plant Community Types and 'species credit' habitat, the number of credits required per hectare (or per individual for flora species) by the Major Projects Credit Calculator can be determined.

Credits required were then analysed separately for indirect impacts and cumulative impacts resulting in the overall ecosystem credits required for each Plant Community Type and 'species credit' species'. This process is detailed in the following sections.

2.3.2 Rehabilitation credits

A comprehensive rehabilitation strategy has been prepared as part of the EIS (Appendix V of the Environmental Impact Statement). The primary objective of rehabilitation in the study area is to manage topsoil to conserve the soil seed bank, nutrients and to encourage the establishment of vegetation. This will be achieved through slashing and mulching of vegetation (rather than clear-felling), minimising impacts on topsoil and the soil seedbank during construction and facilitating natural regeneration through rapid rehabilitation following construction.

Following construction, approximately 50 percent of vegetation clearing associated with the well pads and the gas and water gathering systems (totalling about 587 hectares) will be rehabilitated, as described in the Environmental Impact Statement. The rehabilitation strategy (Appendix V of the Environmental Impact Statement) is an additional mitigation and management measure designed to further reduce the impact of the project on biodiversity values (including threatened and migratory species, populations and ecological communities).

Rehabilitation in the study area has been monitored since 2013. Rehabilitation monitoring undertaken over the past four years has shown that rehabilitation sites approximate 72% of the condition of reference sites, and are clearly on a trajectory to becoming self-sustaining Plant Community Types, representative of pre-occurring types.

The NSW Office of Environment and Heritage has requested that the benefit of rehabilitation be calculated as part of the Biodiversity Offset Strategy after calculation of credits required for impacts.

To validate the number of credits that should be generated for rehabilitation as part of the project, a number of scenarios were reviewed in the BioBanking Credit Calculator (BBCC) to ascertain the maximum number of credits per hectare able to be generated for rehabilitation:

- Scenario 1: All site values set at '0' (bare earth)
- Scenario 2: Site values set at 25% of benchmark for each value (very low site value)
- Scenario 3: Site values set based on the average value recorded at existing rehabilitation sites in the study area (i.e. results achievable within 5 years of rehabilitation)

Under each scenario, the 'gain' for each site value was increased to its maximum (where available). The maximum number of credits were generated for Scenario 2 (10 credits/hectare) and both Scenario 1 and 3 generated a similar number of credits (9 credits/hectare).

However, when you consider the results of the rehabilitation undertaken to date in the study area, site value scores have exceeded the maximum allowable gain for native plant species richness, native ground cover (grasses), native ground cover (other), over-storey regeneration and length of fallen logs. When the weightings for each value are applied in accordance with the BioBanking Assessment Methodology (BBAM), the rehabilitation undertaken to date in the study area results in a 17% overall increase above the best possible gain score using the BBCC.

Due to the demonstrated ability to achieve successful rehabilitation outcomes in short timeframes resulting in self-sustaining Plant Community Types representative of pre-occurring types, the Proponent is requesting a 17% increase on the maximum number of credits able to be generated using the BBCC (i.e. 12 credits/hectare). Due to the proposed rehabilitation techniques (including minimal soil disturbance and management of the topsoil seedbank), the Proponents' proposed rehabilitation far exceeds planting, seeding, or other management activities undertaken on BioBank sites, and is not comparable to mine rehabilitation.

For 'species credit' species impacted by the project, a review of species likely to respond positively to disturbance and rehabilitation was undertaken. The review was based on expert knowledge of each species and relevant literature where available (e.g. recovery plans, threatened species profiles). 'Species credit' species considered likely to respond positively to disturbance and rehabilitation are included in Table 3. This list includes six flora species and only one fauna species. Most of the fauna species have not been included due to the timeframe required to re-establish important habitat features which will be removed such as mature trees, habitat structure and complexity and hollows.

Table 3: 'Species credit' species likely to respond positively to disturbance and rehabilitation

Species	Rationale
<i>Bertya opposens</i>	Has been observed regenerating heavily following road grading and associated clearing. The highest density of individuals has been recorded directly adjacent to roads, with density reducing with distance from disturbance.
<i>Lepidium aschersonii</i>	Has been observed growing in regrowth Brigalow which has been subject to past clearing and intensive grazing.
<i>Lepidium monoplocoides</i>	Has been observed growing in road reserves subject to disturbance and weed infestation.
<i>Polygala linariifolia</i>	Has been observed growing in road reserves subject to disturbance and weed infestation, derived native grassland and on rehabilitation sites within the study area.
<i>Pomaderris queenslandica</i>	Has been observed regenerating heavily following road grading and associated clearing. The highest density of individuals has been recorded directly adjacent to roads, with density reducing with distance from disturbance.
<i>Commersonia procumbens</i> (syn. <i>Rulingia procumbens</i>)	Has been observed regenerating heavily following road grading and associated clearing. The highest density of individuals recorded has been recorded on and directly adjacent to roads, with density reducing with distance from disturbance.
<i>Tylophora linearis</i>	Has been observed regenerating heavily following road grading and associated clearing. The highest density of individuals has been recorded directly adjacent to roads, with density reducing with distance from disturbance.
<i>Macropus dorsalis</i>	This species prefers dense vegetation for sheltering and forages in more open grassy areas which are likely to be created through disturbance and rehabilitation.

For the species included in Table 3, the number of credits generated per individual (flora) or per hectare (fauna) in the BioBanking Credit Calculator is 7.1. To determine the number of credits generated for each species a simple formula was applied:

Number of individuals(flora) or area of habitat(fauna) directly impacted x 0.5 (proportion of area to be rehabilitated) x 7.1 (number of credits generated)

2.3.3 Ecosystem credits

Quantification of impacts and offset liability for both ecosystem and species credit species was undertaken as outlined in the following sections

Direct impact quantification

For a direct impact of 988.9 hectares, the project requires 58,522 ecosystem credits to be offset.

Indirect and cumulative impact quantification

The Credit Calculator is used to assess 'direct' impacts to biodiversity (i.e. vegetation clearance). Section 8.4 of the Framework for Biodiversity Assessment requires the Biobank Assessor to demonstrate minimisation of indirect impacts on biodiversity values using reasonable onsite measures, however it does not specifically require the assessor to quantify indirect impacts. For this assessment, the areas of both indirect and cumulative impacts were assessed in the same way as direct impacts using the appropriate credits per hectare metric determined by the Major Projects Credit Calculator.

For the purposes of offsetting, calculations have been constrained to a 30 year period for indirectly impacted areas – 20 years during development (the expected maximum lifespan of a production well), followed by a 10 year rehabilitation period, after which indirect impacts will cease to function and the indirectly impacted area will be equivalent to areas not affected by the project (i.e. remnant native vegetation and habitat). As such, a 0.3 (30%) multiplier has been applied to indirectly impacted areas when determining final credit liability for indirectly impacted areas. This allows for the operation of individual wells for approximately 20 years (operating life), initial progressive rehabilitation of approximately 50% of the disturbed area associated with the well and linear infrastructure and final rehabilitation following plugging and abandoning of each well. An additional 10 years has been included to allow sufficient time for the rehabilitation to become established. After the 30 year period, indirect site impacts (such as fragmentation, noise, traffic etc.) will cease to operate.

For an indirect impact of 181.1 hectares, the project requires an additional 3,327 ecosystem credits to be offset.

Infrastructure being 'carried forward' as part of the Narrabri Gas Project includes a series of wells, flowlines and facilities as shown on Figure 2. This includes infrastructure being carried forward for which impacts have already been offset, and infrastructure being carried forward for which impacts are to be offset as part of the project. For the purposes of this assessment, infrastructure being 'carried forward' are referred to as 'cumulative impacts'.

For a cumulative impact of 79.3 hectares, the project requires an additional 4,784 credits to be offset.

The calculations of indirect and cumulative impacts are considered to be additional measures (i.e. they are not required to be directly assessed by the Framework for Biodiversity Assessment), but have been included to account for and in recognition of the full impacts of the project.

Immediate rehabilitation quantification

The construction and rehabilitation methodology proposed as part of the project differs from other resource developments such as mine site rehabilitation in that it utilises the inherent capacity of the native vegetation in the study area to regenerate naturally as discussed in **Section 2.3.1**.

Due to the limited disturbance to soils and the regolith, the development is unique in that it is conducive to natural rehabilitation, direct impacts (988.8 ha) were split between those areas which will be rehabilitated immediately following construction (586.7 ha) and areas with no immediate rehabilitation (402.2 ha).

Up to 55% of each well pad (0.55 ha) and up to 50% of the width of linear infrastructure (gas and water gathering systems and access tracks) will be rehabilitated immediately following construction.

For areas subject to immediate rehabilitation following construction (586.7 hectares), a total of 7,040 credits are generated.

Summary of ecosystem credit requirements

The results of this ecosystem credit assessment are summarised in **Table 4** which indicate that a total of 66,633 ecosystem credits are required to offset the direct, indirect and cumulative impacts of the project.

The results of the rehabilitation assessment for ecosystem credit species is also summarised in **Table 4** which indicates that a total of 7,040 ecosystem credits are generated. This reduces the overall offset ecosystem credit liability of the project to 59,593 credits (an 11% reduction).

Using the OEH credit converter which assumes an average Biobank site will generate 9.3 credits per ha, the equivalent offset area is 6,408 hectares. This equates to a 6.5:1 offset ratio against a direct impact of 988.8 hectares or a 5.1:1 offset ratio against a combined direct, indirect and cumulative impact of 1,249.3 ha.

The Major Projects Credit Calculator specifies that the offsets can be secured in a range of similar Plant Community Types, across a number of IBRA subregions and in accordance with the Framework for Biodiversity Assessment, meet the 'like-for-like' offset principle (Principle 3). Additionally, the variation criteria in the Framework for Biodiversity Assessment allows Plant Community Types in the same vegetation 'formation' to be used as offsets as well as species in the same 'order' (fauna) or family (flora) provided they have undergone similar levels of clearing or threat.

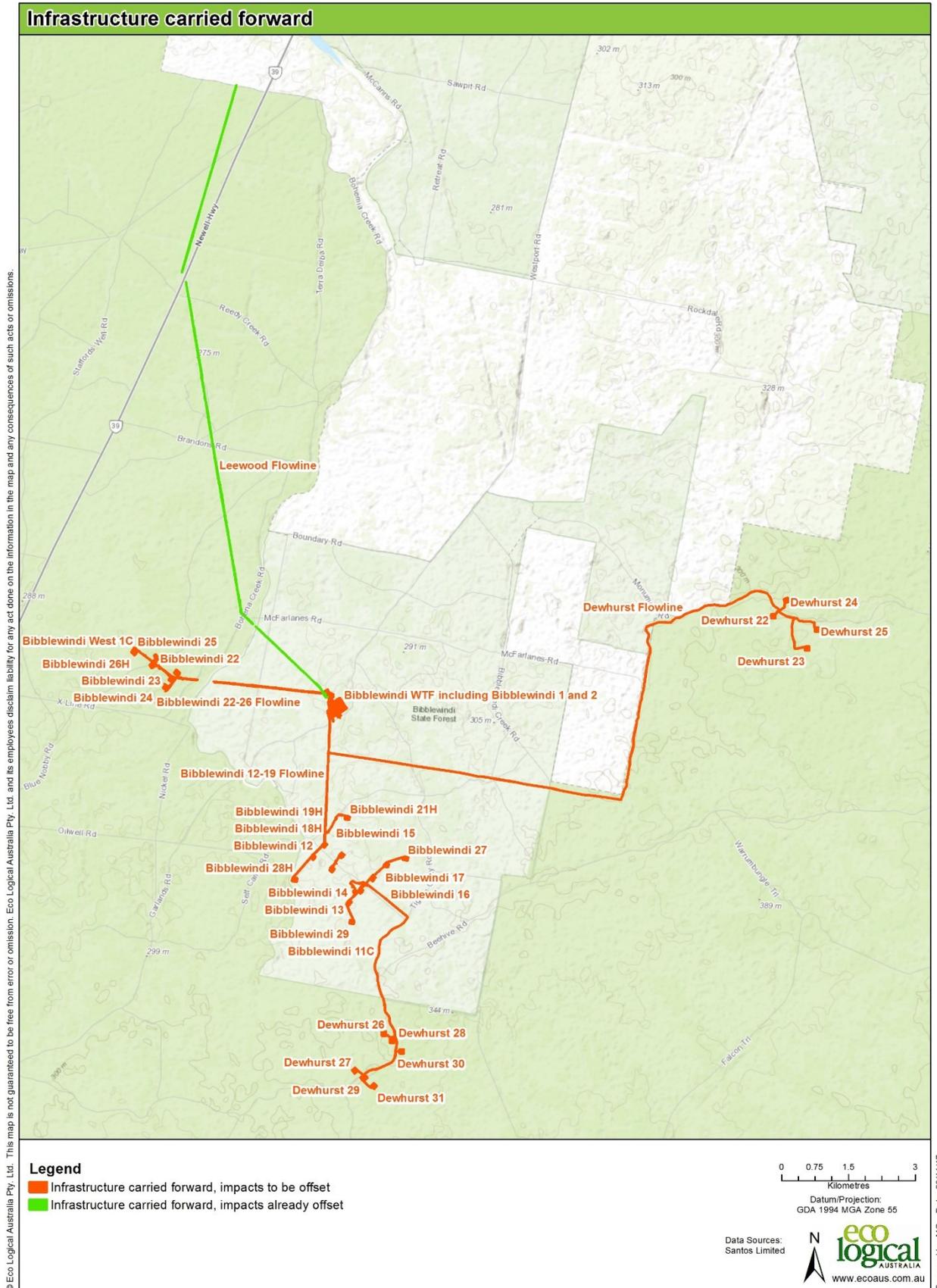


Figure 2: Infrastructure 'carried forward'

Table 4: Major Projects Assessment (Version 4.0) – Ecosystem Credits Required

VegZone	BVT (2014)	PCT	Vegetation Zone	Plant Community Type Name	Direct Impacts	Credits required from MPCC	Indirect Impacts	Credits required using credits/ha generated by MPCC	Cumulative Impacts	Credits required using credits/ha generated by MPCC	Total Impact		Credits / ha generated by MPCC	Rehabilitation (Post Impact)		Total Offset required based on credits/ha generated by MPCC	
					Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits		Area (ha)	# Credits generated @ 12 credits/ha	#Credits	Approximate Offset Area (ha) @ 9.3 credits/ ha
Narrabri Gas Project 2018 - Part 1 (Proposal ID 0027/2018/4783MP)																	
1	NA219	27	Moderate/Good	Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	0.1	5.0	0.0	0.0	0.0	0.0	0.1	5.0	50.0	0.1	0.7	4	0.5
2	NA219	27	Moderate/Good_Derived Grassland	Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	0.5	20.0	0.0	0.0	0.0	0.0	0.5	20.0	40.0	0.3	3.7	16	1.8
3	NA117	35	Moderate/Good	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	19.3	1,229.0	3.9	74.5	0.0	0.0	23.2	1,303.5	63.7	12.0	144.0	1,160	124.7
4	NA117	35	Moderate/Good_Derived Grassland	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	37.2	1,301.0	0.0	0.0	0.0	0.0	37.2	1,301.0	35.0	23.3	279.0	1,022	109.9
5	NA102	55	Moderate/Good	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	3.9	207.0	0.8	12.7	0.0	0.0	4.7	219.7	52.9	2.4	29.2	191	20.5
6	NA102	55	Moderate/Good_Derived Grassland	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	1.7	65.0	0.0	0.0	0.0	0.0	1.7	65.0	38.2	1.1	12.7	52	5.6
7	NA179	88	Moderate/Good	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	40.8	2,684.0	8.2	161.6	0.0	0.0	49.0	2,845.6	65.8	22.0	263.4	2,582	277.7
8	NA179	88	Moderate/Good_Derived Grassland	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	8.8	283.0	0.0	0.0	0.0	0.0	8.8	283.0	32.2	5.5	66.0	217	23.3
9	NA121	141	Moderate/Good	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	19.5	701.0	4.0	43.1	0.5	17.4	24.0	761.5	35.9	12.1	145.6	616	66.2

VegZone	BVT (2014)	PCT	Vegetation Zone	Plant Community Type Name	Direct Impacts	Credits required from MPCC	Indirect Impacts	Credits required using credits/ha generated by MPCC	Cumulative Impacts	Credits required using credits/ha generated by MPCC	Total Impact		Credits / ha generated by MPCC	Rehabilitation (Post Impact)		Total Offset required based on credits/ha generated by MPCC	
					Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits		Area (ha)	# Credits generated @ 12 credits/ha	#Credits	Approximate Offset Area (ha) @ 9.3 credits/ ha
10	NA141	202	Moderate/Good	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South Bioregion (including Pilliga) and Nandewar Bioregion	5.9	458.0	1.2	28.6	2.1	161.9	9.2	648.5	77.6	3.6	42.6	606	65.2
Subtotal					137.7	6,953.0	18.1	320.6	2.6	179.2	158.4	7,452.8		82.2	986.9	6,466.0	695.3

Narrabri Gas Project 2018 - Part 2 (Proposal ID 0027/2018/4784MP)

1	NA292	256	Moderate/Good	Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern Brigalow Belt South Bioregion	0.3	14.0	0.1	1.4	0.0	0.0	0.4	15.4	46.7	0.2	2.3	13	1.4
2	NA279	408	Moderate/Good	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	33.3	2,073.0	6.8	127.0	3.4	210.5	43.5	2,410.5	62.3	20.7	248.4	2,162	232.5
3	NA279	408	Moderate/Good_Derived Grassland	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	0.4	10.0	0.0	0.0	0.0	0.0	0.4	10.0	25.0	0.3	3.0	7	0.8
4	NA314	398	Moderate/Good	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north Brigalow Belt South Bioregion	323.4	19,127.0	63.4	1,124.0	57.5	3,400.3	444.2	23,651.4	59.1	188.1	2,257.7	21,394	2,300.4
5	NA314	398	Moderate/Good_Derived Grassland	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north Brigalow Belt South Bioregion	3.9	184.0	0.0	0.0	0.0	0.0	3.9	184.0	47.2	2.4	29.3	155	16.6
6	NA255	399	Moderate/Good	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	3.4	203.0	0.7	11.8	0.1	5.4	4.2	220.2	59.7	1.8	21.6	199	21.4

VegZone	BVT (2014)	PCT	Vegetation Zone	Plant Community Type Name	Direct Impacts	Credits required from MPCC	Indirect Impacts	Credits required using credits/ha generated by MPCC	Cumulative Impacts	Credits required using credits/ha generated by MPCC	Total Impact		Credits / ha generated by MPCC	Rehabilitation (Post Impact)		Total Offset required based on credits/ha generated by MPCC	
					Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits		Area (ha)	# Credits generated @ 12 credits/ha	#Credits	Approximate Offset Area (ha) @ 9.3 credits/ ha
7	NA255	399	Moderate/Good_Derived Grassland	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	1.6	-2	-0.2
8	NA307	402	Moderate/Good	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, Brigalow Belt South Bioregion	1.6	88.0	0.3	5.0	0.0	0.0	1.9	93.0	55.0	1.0	12.0	81	8.7
9	NA307	402	Moderate/Good_Derived Grassland	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, Brigalow Belt South Bioregion	1.6	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	1.0	12.0	-12	-1.3
10	NA294	379	Moderate/Good	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the Brigalow Belt South Bioregion	2.7	197.0	0.5	10.9	0.0	0.0	3.2	207.9	72.7	1.7	20.2	188	20.2
Subtotal					370.8	21,896.0	71.7	1,280.1	61.0	3,616.2	503.5	26,792.3		217.3	2,608.0	24,184.4	2,600.5

Narrabri Gas Project 2018 - Part 3 (Proposal ID 0027/2018/4785MP)

1	NA324	397	Moderate/Good	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	1.0	60.0	0.2	3.6	0.0	0.0	1.2	63.6	59.4	0.6	7.6	56	6.0
2	NA324	397	Moderate/Good_Derived Grassland	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	1.3	33.0	0.0	0.0	0.0	0.0	1.3	33.0	25.4	0.8	9.7	23	2.5
3	NA338	401	Moderate/Good	Rough-barked Apple - Blakely's Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	46.4	3,288.0	9.2	196.0	2.3	165.3	58.0	3,649.3	70.9	27.3	327.6	3,322	357.2
4	NA338	401	Moderate/Good_Derived Grassland	Rough-barked Apple - Blakely's Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	18.1	646.0	0.0	0.0	0.0	0.0	18.1	646.0	35.7	11.3	135.7	510	54.9

VegZone	BVT (2014)	PCT	Vegetation Zone	Plant Community Type Name	Direct Impacts	Credits required from MPCC	Indirect Impacts	Credits required using credits/ha generated by MPCC	Cumulative Impacts	Credits required using credits/ha generated by MPCC	Total Impact		Credits / ha generated by MPCC	Rehabilitation (Post Impact)		Total Offset required based on credits/ha generated by MPCC	
					Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits		Area (ha)	# Credits generated @ 12 credits/ha	#Credits	Approximate Offset Area (ha) @ 9.3 credits/ ha
5	NA326	404	Moderate/Good	Red Ironbark - White Bloodwood +/- Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	86.6	5,934.0	17.6	361.8	0.0	0.0	104.2	6,295.8	68.5	53.8	646.1	5,650	607.5
6	NA390	405	Moderate/Good	White Bloodwood - Red Ironbark - Black Cypress Pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	247.1	15,096.0	48.5	888.2	13.3	815.0	308.9	16,799.2	61.1	143.6	1,722.7	15,076	1,621.1
7	NA390	405	Moderate/Good_Derived Grassland	White Bloodwood - Red Ironbark - Black Cypress Pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	1.9	72.0	0.0	0.0	0.0	0.0	1.9	72.0	37.9	1.2	14.3	58	6.2
8	NA389	406	Moderate/Good	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	69.0	4,000.0	14.0	243.5	0.0	0.0	83.0	4,243.5	58.0	42.9	514.8	3,729	400.9
9	NA409	418	Moderate/Good	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, Brigalow Belt South Bioregion	0.2	13.0	0.1	1.9	0.0	0.0	0.3	14.9	61.9	0.1	1.6	13	1.4
10	NA409	418	Moderate/Good_Derived Grassland	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, Brigalow Belt South Bioregion	0.3	8.0	0.0	0.0	0.0	0.0	0.3	8.0	26.7	0.2	2.3	6	0.6
11	NA363	425	Moderate/Good	Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	8.4	523.0	1.7	31.7	0.1	8.0	10.2	562.7	62.2	5.2	62.8	500	53.8
Subtotal					480.3	29,673.0	91.3	1,726.6	15.8	988.3	587.4	32,387.9		287.1	3,445.1	28,942.8	3,112.1
Total					989	58,522	181	3,327	79	4,784	1,249	66,633		587	7,040	59,593	6,408

2.3.4 Species credits

Six threatened fauna species and nine threatened flora species recorded in the study area are listed as 'species credit' species under the Framework for Biodiversity Assessment (**Table 5** and **Table 6**). Credits required for flora species range from 676 to 1,087,674 credits. Credits required for fauna species range from 4,255 to 33,740 credits. *Lepidium aschersonii* requires the largest number of flora credits to be offset, while *Hoplocephalus bitorquatus* (Pale-headed Snake) requires the largest number of fauna credits to be offset. The total 'species credit' liability is 1,418,928 credits for flora species and 138,806 credits for fauna species.

The results of the rehabilitation assessment for ecosystem credit species is also summarised in Table 5 and Table 6 which indicates that a total of 332,106 credits are generated for flora species and 3,510 credits for fauna species. In respect to fauna, species credits have only been generated for Black-striped Wallaby as described in **Section 2.3.2** and **Table 3** as the favoured habitat for this species is likely to be created through disturbance and rehabilitation proposed as part of the project.

This reduces the overall offset species credit liability of the project to 1,086,822 credits for flora species and 135,296 credits for fauna species.

Table 5: Major Projects Assessment (Version 4.0) – Flora Species Credits Required

Narrabri Gas Project 2018 - Part 1 (Proposal ID 0027/2018/4783MP)		Direct and Indirect Impacts		Cumulative Impacts		Total Impact		Credits / plant generated by MPCC	Likely to respond positively to rehabilitation?	Rehabilitation		Total Offset Required	
Species	TS offset multiplier	# Individuals	# Credits required from MPCC	# Individuals	# Credits required using credits/ha generated by MPCC	# Individuals	# Credits			# Individuals	# Credits	Offset required Credits	Offset required (individuals)
<i>Bertya opposens</i>	1.4	10,309	144,326	0	0	10,309	144,326	14	Yes	5,155	36,597	107,729	17,955
<i>Diuris tricolor</i>	1.3	52	676	0	0	52	676	13	No	0	0	676	113
<i>Lepidium aschersonii</i>	1.4	77,691	1,087,674	0	0	77,691	1,087,674	14	Yes	38,846	275,803	811,871	135,312
<i>Lepidium monoplocoides</i>	1.5	1,116	16,740	0	0	1,116	16,740	15	Yes	558	3,962	12,778	2,130
<i>Polygala linariifolia</i>	1.5	252	3,780	0	0	252	3,780	15	Yes	126	895	2,885	481
<i>Pomaderris queenslandica</i>	1.4	467	6,538	0	0	467	6,538	14	Yes	234	1,658	4,880	813
<i>Pterostylis cobarensis</i>	1.3	6,658	86,554	706	9,178	7,364	95,732	13	No	0	0	95,732	15,955
<i>Commersonia procumbens</i>	1.5	3,716	55,740	0	0	3,716	55,740	15	Yes	1,858	13,192	42,548	7,091
<i>Tylophora linearis</i>	1.3	513	6,669	81	1,053	594	7,722	13	No	0	0	7,722	1,287

Table 6: Major Projects Assessment (Version 4.0) – Fauna Species Credits Required

Species	TS offset multiplier	Direct Impacts		Indirect Impacts		Cumulative Impacts		Total Impact		Credits / ha generated by MPCC	Likely to respond positively to rehabilitation?	Rehabilitation		Total Offset Required	
		Area (ha)	Credits required from MPCC	Area (ha)	# Credits required using credits/ha generated by MPCC	Area (ha)	# Credits required using credits/ha generated by MPCC	Area (ha)	# Credits			Area (ha)	# Credits	Offset required Credits	Offset required (ha)
<i>Macropus dorsalis</i>	2.7	988.8	26,698	181.1	1,467	84.8	2,290	1,254.7	30,455	27	Yes	494	3,510	26,944	3,275
<i>Cercartetus nanus</i>	2	774.8	15,496	153.0	918	76.8	1,536	1,004.6	17,950	20	No	0	0	17,950	1,930
<i>Hoplocephalus bitorquatus</i>	3.3	885.0	29,205	175.4	1,737	84.8	2,798	1,145.2	33,740	33	No	0	0	33,740	3,628
<i>Petaurus norfolcensis</i>	2.2	861.8	18,960	170.7	1,127	84.8	1,866	1,117.3	21,952	22	No	0	0	21,952	2,360
<i>Anthochaera phrygia</i>	8	48.0	3,840	9.5	228	2.3	187	59.9	4,255	80	No	0	0	4,255	458
<i>Phascolarctos cinereus</i>	2.7	988.8	26,698	181.0	1,466	84.8	2,290	1,254.6	30,454	27	No	0	0	30,454	3,275

2.3.5 Hollow-bearing trees

The removal of large hollows (>300 mm) will be compensated for by at least a 1:1 replacement with either artificial nestboxes or hollows. Specific detail regarding offset ratios, locations for hollow re-instatement and an implementation strategy will be developed as part of the Biodiversity Offset Management Plan for the project.

2.3.6 Assumptions and limitations

- Changes to Area/Perimeter ratio as a result of the project are conservative.
- Each vegetation zones was given a maximum patch size of 1,001 hectares which is likely to be conservative, particularly for vegetation in the north-west of the study area.
- Manual updates to overstorey regeneration for some vegetation zones as described above.
- Threatened species multipliers in the Major Project Credit Calculator were updated manually using the latest up to date information archived from Bionet for a number of species.
- Biometric Vegetation Types for the Namoi CMA were updated in October 2014. Vegetation stratification, habitat stratification, population modelling and cumulative impacts are reported on for Biometric Vegetation Types October 2008 (ELA, 2015), while offset calculations have been undertaken using Biometric Vegetation Types October 2014 in accordance with the NSW Biodiversity Offset Policy for Major Projects and Framework for Biodiversity Assessment.
- The study area is intersected equally by the Pilliga A and Pilliga Outwash Catchment Management Authority (CMA) subregions. Vegetation zones were entered against the Pilliga Outwash CMA subregion.

2.4 EPBC offset requirements

The Commonwealth Department of the Environment (DoE) EPBC Act 'offset assessment guide' (DSEWPaC, 2012) applies to new referrals and variations to approval conditions from 2 October 2012 and projects currently under assessment. Offsets are only relevant to EPBC Act approvals declared as a 'controlled action' and where there is likely to be a residual 'significant' impact (DSEWPaC, 2012).

The project was referred to the Commonwealth Department of the Environment on 3 November 2014 (2014/7376). The project was determined a 'controlled action' on 1 December 2014 due to potential impacts on listed threatened species and communities, a water resource, in relation to coal seam gas development and large coal mining development and commonwealth land. Assessment of the project has been delegated to the State under the assessment bilateral agreement with the NSW Government.

As the NSW Biodiversity Offset Policy for Major Projects was developed with full consideration of Matters of National Environmental Significance, offsets determined under the *NSW Biodiversity Offset Policy for Major Projects* are considered to satisfy EPBC offset requirements.

The DoE offset policy states that impacts should first be avoided and mitigated as offsets do not reduce the impacts of a proposed action. Offsets will not be considered until all reasonable avoidance and mitigation measures are considered. Measures taken to avoid, minimise and mitigate the impacts of the project are outlined in Section 7 and Section 8 of the Ecological Impact Assessment of the project (ELA, 2015).

Direct offsets are to meet a minimum 90 percent of the measurable environmental gain for the impacted protected matter. A conservation gain for the remaining offset liability may be achieved by:

- improving existing habitat for the protected matter
- creating new habitat for the protected matter
- reducing threats to the protected matter

- increasing the values of a heritage place
- averting the loss of a protected matter or its habitat that is under threat.

The delivery of offsets that establish positive social or economic co-benefits are encouraged such as increasing landscape connectivity, offsets that employ local indigenous rangers to undertake management actions or pay rural landholders to protect and manage land for conservation purposes.

The DoE policy states that offset packages should be developed in consultation with the Department and that if the Department is satisfied that the offset activities are suitable, the Department will consider the magnitude and composition of the preliminary offset package. The Department will take a range of considerations at both the impact and proposed offset site(s) into account, including:

Matters to be considered at the impact site:

1. Presence and conservation status of protected matters likely to be impacted by the proposed action.
2. Specific attributes of the protected matter being impacted at a site, for example: the type of threatened species or ecological community habitat, the quality of habitat, population attributes such as recruitment or mortality, landscape attributes such as habitat connectivity, or heritage values.
3. Scale and nature of the impacts of the proposed action – including direct and indirect impacts.
4. Duration of the impact (not of the action).

Matters to be considered at the offset site:

1. Extent to which the proposed offset actions correlate to, and adequately compensate for, the impacts on the attributes for the protected matter.
2. Conservation gain to be achieved by the offset. This may be through positive management activities that improve the viability of the protected matter or averting the future loss, degradation or damage of the protected matter.
3. Current land tenure of the offset and the proposed method of securing and managing the offset for the life of the impact.
4. Time it will take to achieve the proposed conservation gain.
5. Level of certainty that the proposed offset will be successful. In the case of uncertainty, such as using a previously untested conservation technique, a greater variety and/or quantity of offsets may be required to minimise risk.
6. Suitability of the location of the offset site. In most cases this will be as close to the impact site as possible. However, if it can be shown that a greater conservation benefit for the impacted protected matter can be achieved by providing an offset further away, then this will be considered.

It is noted that under the EPBC Act Environmental Offsets Policy consideration of offsets is only required for Matters of National Environmental Significance where there remains a residual significant impact after avoidance and mitigation measures.

When considering the magnitude and duration of direct, indirect and cumulative impacts; partial rehabilitation proposed and demonstrated rehabilitation success; and proposed mitigation measures such as the Ecological Scouting Framework and the nil-tenure feral animal control strategy, there is unlikely to be a significant adverse impact on Matters of National Environmental Significance as a result of the project. Nevertheless, Matters of National Environmental Significance have been assessed and offsets have been determined under the *NSW Biodiversity Offset Policy for Major Projects*).

2.5 Cultural Heritage

Consideration of Aboriginal cultural heritage values is a key component of the Biodiversity Offset Strategy. Cultural heritage will be identified and integrated into biodiversity offsets in three ways:

- Aboriginal cultural heritage values such as important sites, places of traditional or recent significance and culturally important plants and animals will be identified as part of the selection of suitable land-based biodiversity offsets.
- Community access to biodiversity offset areas will be facilitated where practicable.
- Community management of offset lands will be encouraged.

2.5.1 Cultural heritage offsets

Aboriginal cultural heritage values will be identified within suitable lands intended for biodiversity offsets. Considerations for Aboriginal cultural heritage values for inclusion in Biodiversity Offsets will include:

- Existing important sites such as burials, stone arrangements and earthen circles, carved or scarred trees, rock shelters, grinding grooves, quarries, mounds, hearths and ovens, stone artefact concentrations and shell middens.
- Places of traditional and anthropological significance.
- Places of recent historic and anthropological significance.
- Culturally important plants (refer **Appendix A** (CQCHM, 2014)) and animals.

These values will be considered in assessing the relative merits of one potential offset site over another.

2.5.2 Community access to cultural heritage offsets

Community access to land-based biodiversity offset areas will be facilitated where practicable. Access will be negotiated under the following principles. Aboriginal people should be able to:

- Access, use and enjoy, move about and hold meetings on the offset area.
- Camp, erect shelters and other structures on the offset area in limited designated areas.
- Hunt, fish and use the natural resources of the offset area (including water, food, medicinal plants, timber, tubers, charcoal, wax, stone, ochre and resin as well as materials for fabricating tools, hunting implements, making artwork and musical instruments) provided the activities are undertaken in an ecologically sustainable manner and not contradict the objectives of biodiversity conservation.
- Conducting ancillary cultural activities such as burning programs to ensure the continued viability of the area for cultural purposes, provided the activities are undertaken in an ecologically sustainable manner and not contradict the objectives of biodiversity conservation.
- Conduct and participate in cultural and spiritual activities, ceremonies and rituals.
- Maintain and protect places of importance under traditional laws, customs and practices in the offset area.

2.5.3 Community management of offset lands

The Proponent will enter into agreements with appropriately qualified Aboriginal people to manage certain lands acquired as land-based biodiversity offsets and will identify land management funding that can be used for training opportunities to acquire the necessary skills where required. Community management of land will ensure that proposed management regimes will not impair other Aboriginal cultural heritage values.

3 Biodiversity offset package

The Biodiversity Offset Package for the project will deliver environmental, cultural and socio/economic benefits through:

- Land-based offsets which will seek to increase landscape connectivity and conservation of ecological values unique to the Pilliga Region.
- Incorporation of some areas of land into the offset package because of their Aboriginal cultural heritage values, or that the land is owned by the Aboriginal community, as well as their biodiversity values.
- Providing ongoing access to this land for traditional cultural activities and practices.
- Actively involve Aboriginal people in the management of some offset land and implementation of supplementary measures.

The Biodiversity Offset Package for the project will contain a combination of:

- **Like-for-like offsets** secured via an appropriate conservation mechanism (including purchase and retirement of biodiversity credits (where available), protection under Biodiversity Stewardship Agreements, or reservation under the NSW *National Parks and Wildlife Act 1974*).
- **Supplementary measures** developed and funded through Planning Agreements (PAs) under the NSW *Environmental Planning and Assessment Act 1979* (EPA Act).
- **Compensatory measures** such as Koala research.
- **NSW Biodiversity Offsets Fund for Major Projects** will be used for remaining offset liability (when established).

3.1 Land based offset sites

The availability and suitability of potential offset sites in the region has been investigated as part of the response to submissions. This process has sought to demonstrate the majority of the like-for-like offset liability of the project could be achieved through land based offset sites. This process has included:

1. Checking the biobanking public register and having an expression of interest (EOI) for credits wanted for at least six months.
2. Liaising with an OEH office and Narrabri Council to obtain a list of potential sites that meet the requirements for offsetting.
3. Considering properties for sale in the region.

This process included identifying lands with appropriate conservation values in proximity to the project, identifying where these lands have potential to provide like-for-like vegetation and threatened species habitat, and where cost effective management can be implemented to improve the overall conservation value of the land.

Wherever possible, further detailed investigation of potential offsets will be directed to areas adjacent to existing conservation areas to improve the overall extent and connectivity of conserved land in the region.

Should potential offsets be considered not feasible, suitable evidence will be provided (e.g. unwillingness of landowner to sell or establish a Biobank site, or sale price significantly above market rates).

3.1.1 Biobanking public register and expression of interest

An expression of interest was lodged on the 'credits wanted register' on 27 February 2017. While some initial interest was generated, no land was nominated which could substantially satisfy the requirements of the project.

A review of the Biobanking public register was undertaken on 14 December 2017. Both the Biobanking credits register and the Biobank site expression of interest register were reviewed. No ecosystem or species credits are currently available for the project.

There are three sites listed under the Biobank site expression of interest register which may be suitable (in part) as land based offset sites for the project as outlined in Table 7. If these sites are still available, and the landowner is amenable to the establishment of a Biodiversity Stewardship Site on their land, then they have the potential to contribute up to 50% of the total offset liability of the project depending on the biodiversity values present.

Table 7: Biobank site expressions of interest

EOI ID	IBRA sub-region	LGA	Vegetation formation	Area(ha)
15	Pilliga Outwash - Namoi	Narrabri Shire Council	Dry sclerophyll forests (shrubby) & others	2,570
78	Pilliga - Central West	Warrumbungle Shire Council	Grassy woodlands & others	372
297	Pilliga Outwash - Namoi	Narrabri Shire Council	Dry sclerophyll forests (shrub/grass)	355
Total				3,297

3.1.2 Liaison with OEH and Narrabri Council

Preliminary liaison with OEH and Narrabri Council has not resulted in any potential offset sites which could satisfy the requirements of the project being nominated.

3.1.3 Analysis of freehold land in the Pilliga and Pilliga Outwash IBRA subregions

The availability of freehold land in the Pilliga and Pilliga Outwash IBRA subregions was investigated as part of the development of the biodiversity offset strategy. This analysis demonstrates the potential availability of suitable offsets in the region.

To identify suitable freehold land and biodiversity values present, the following spatial analysis was undertaken:

- The Pilliga and Pilliga Outwash IBRA subregions were merged to form a 'study area' data layer
- The Border Rivers Gwydir / Namoi and Central West / Lachlan Regional Native Vegetation PCT Maps (OEH 2015a,b) were merged and clipped to the study area to form a 'PCT' data layer
- The NSW Cadastre was clipped to the study area and all records denoting freehold land were selected to form a 'freehold land' data layer
- The PCT and freehold land data layers were unioned and the following fields were added:
 - 'patch veg' which identifies PCTs included in the patch size analysis (described below)

- ‘TargetedPCTs’ which identifies if the mapped PCTs correspond to any of the potential PCTs suitable for offsetting as defined by the Major Projects Credit Calculator
- ‘VariatPCTs’ which identifies if the mapped PCTs correspond to any of the potential PCTs suitable for offsetting based on the variation rules outlined in the NSW Biodiversity Offset Policy for Major Projects (i.e. the same vegetation formation that has undergone an equal or greater amount of clearing)
- Patches of native vegetation were defined in accordance with the FBA, whereby patches that were separated by less than 100 m were considered part of the same patch. This step was required to eliminate breaks in mapping caused by roads, powerlines, fences etc.
- Areas of consolidated vegetation (greater than 1,000 hectares) were identified through a data review. 1,000 hectares was selected as large, consolidated patches of native vegetation are likely to provide better conservation outcomes as well as providing value for money.

For PCTs targeted as part of the analysis (those ‘like for like’ communities included in the credit profile for each PCT), a total of 282,000 hectares of native vegetation was identified on freehold land in the study area (Table 8). Following the variation rules permitted under the FBA (subject to being able to demonstrate not being able to locate suitable ‘like for like’ offsets), there is no meaningful difference in the total amount of native vegetation available on freehold land (Table 8). This is due to the large number of PCTs (and corresponding ‘like for like’ communities) already included as part of the targeted analysis. The key difference is that for each targeted PCT, there is greater flexibility in which PCTs offsets are permitted in (Table 8).

It is not possible to undertake a detailed analysis of the availability of ‘species credit’ species from a desktop perspective without undertaking detailed field investigation. However, considering the ‘like for like’ nature of these PCTs, it is considered highly likely that suitable habitat for the required ‘species credit’ species would occur on the freehold land identified in the study area. To confirm this assumption, a review of the Threatened Species Profile Database (TSPD) was undertaken which identified that all of the ‘species credit’ species required to be offset by the project are associated with on average 24 of the ‘like for like’ PCTs identified in the regional analysis (range 1 and 43 PCTs per species).

To further support this conclusion, there are records in the Atlas of NSW Wildlife (OEH, 2017b) for 73% of the ‘species credit’ species required to be offset as part of the project on freehold land identified as part of this analysis. This is significant due to the private tenure and relatively low amount of survey in the region.

Table 8: Potential offsets available on freehold land in the study area

PCT	Biometric Vegetation Type	Offset Required (ha)	Potential offset available (ha)	Potential offset available (variation rules)
27	Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	2.4	361	10,252
35	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	244.0	7,441	7,441

PCT	Biometric Vegetation Type	Offset Required (ha)	Potential offset available (ha)	Potential offset available (variation rules)
55	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	25.9	2,451	10,252
88	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	293.0	17,785	17,785
141	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	66.7	45,964	72,819
202	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South Bioregion (including Pilliga) and Nandewar Bioregion	65.2	1,286	1,286
256	Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern Brigalow Belt South Bioregion	1.4	138	2,404
379	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the Brigalow Belt South Bioregion	17.0	77,796	198,129
397	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	8.3	42,901	50,720
398	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north Brigalow Belt South Bioregion	2,363.1	64,024	83,722
399	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	21.9	77,796	198,129
401	Rough-barked Apple - Blakely's Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	388.2	44,537	53,528
402	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, Brigalow Belt South Bioregion	11.0	20,867	8,408

PCT	Biometric Vegetation Type	Offset Required (ha)	Potential offset available (ha)	Potential offset available (variation rules)
404	Red Ironbark - White Bloodwood +/- Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	609.2	77,796	198,129
405	White Bloodwood - Red Ironbark - Black Cypress Pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	1,663.5	77,796	179,283
406	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	402.2	77,796	198,182
408	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	233.9	77,796	179,283
418	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, Brigalow Belt South Bioregion	2.0	24,620	72,819
425	Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	52.5	77,796	198,129
Total		6,472	282,861[#]	282,539[#]

[#]This is the total of all potential offset PCTs, not a cumulative total for each PCT. Cumulative totals for all PCT do not provide an accurate representation of available vegetation as each PCT impacted can generally be offset with multiple PCTs which then may be also suitable to offset other impacted PCTs.

3.1.4 Properties for sale in the region

Properties currently for sale in the region (defined as the Brigalow Belt South IBRA Bioregion) were investigated as part of the development of the biodiversity offset strategy. To identify suitable properties and their biodiversity values, the following criteria were used:

- Rural properties in Narrabri, Coonabarabran and Pilliga and surrounding areas.
- Minimum land size of (202 hectares) 500 acres.
- Suitable properties (i.e. those with large areas of remnant vegetation) were manually selected based on a review of aerial photography.
- Lot/DPs for the suitable properties were identified and mapped.
- Properties outside of the Brigalow Belt South IBRA Bioregion were excluded.
- Regional vegetation mapping (OEH 2015a,b) was then queried to identify the type and quantum of likely PCTs present.

Searches of www.realestate.com.au were undertaken on 11 December 2017 and returned a total 11 suitable properties. Based on regional vegetation mapping, a total of 6,796 hectares of native vegetation was identified across these 11 properties (Table 9). The total value of these 11 properties is approximately \$8.5M and they cover a total area of approximately 8,300 hectares (of which approximately 82% is vegetated). To ensure the privacy of these landholders, the details and locations of properties have been withheld.

It is not possible to undertake a detailed analysis of the availability of 'species credit' species from a desktop perspective for properties for sale in the region without undertaking detailed field investigation. However, considering the 'like for like' nature of these Plant Community Types, it is considered highly likely that suitable habitat for the required 'species credit' species would occur on the properties for sale identified in the region. To confirm this assumption, a review of the Threatened Species Profile Database (TSPD) was undertaken which identified that all of the 'species credit' species required to be offset by the project are associated with on average 9 of the 'like for like' PCTs identified in the regional analysis (range 3 and 19 PCTs per species).

There are no records in the Atlas of NSW Wildlife (OEH, 2017b) for the 'species credit' species required to be offset as part of the project on land currently for sale. This is not unexpected given the private tenure and relatively low amount of survey in the region.

Table 9: Type and quantum of PCTs present on properties for sale

PCT	PCT Name	Hectares
1	Candidate Native Grasslands	1,300
35	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	558
56	Poplar Box - Belah woodland on clay-loam soils on alluvial plains of north-central NSW	7
81	Western Grey Box - cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion	72
88	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	321
101	Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion	12
168	Derived Copperburr shrubland of the NSW northern inland alluvial floodplains	1
244	Poplar Box grassy woodland on alluvial clay-loam soils mainly in the temperate (hot summer) climate zone of central NSW (wheatbelt).	1
379	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the Brigalow Belt South Bioregion	5

PCT	PCT Name	Hectares
397	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	658
398	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north Brigalow Belt South Bioregion	483
399	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	182
401	Rough-barked Apple - Blakelys Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	1,078
411	Buloke - White Cypress Pine woodland on outwash plains in the Pilliga Scrub and Narrabri regions, Brigalow Belt South Bioregion	521
417	Black Cypress Pine - Narrow-leaved Ironbark - red gum +/- White Bloodwood shrubby open forest on hills of the southern Pilliga, Coonabarabran and Garawilla regions, Brigalow Belt South Bioregion	847
433	White Box grassy woodland to open woodland on basalt flats and rises in the Liverpool Plains sub-region, BBS Bioregion	0
440	Red Stringybark - Narrow-leaved Ironbark - Black Cypress Pine - hill red gum sandstone woodland of southern NSW Brigalow Belt South Bioregion	525
455	Rough-barked Apple - Red Stringybark - Black Cypress Pine - red gum sand valley woodland of the Garawilla region, Brigalow Belt South Bioregion	2
457	White Bloodwood - Red Ironbark - Black Cypress Pine woodland on sandstone hills in the Garawilla - Liverpool Plains region, Brigalow Belt South Bioregion	113
467	Blue-leaved Ironbark - Black Cypress Pine shrubby sandstone open forest in the southern Brigalow Belt South Bioregion (including Goonoo)	17
468	Narrow-leaved Ironbark - Black Cypress Pine +/- Blakelys Red Gum shrubby open forest on sandstone low hills in the southern Brigalow Belt South Bioregion (including Goonoo)	3
511	Queensland Bluegrass - Redleg Grass - Rats Tail Grass - spear grass - panic grass derived grassland of the Nandewar Bioregion and Brigalow Belt South Bioregion	88
Total		6,796

3.1.5 Feasibility of offsets

It is not possible to determine the feasibility of land based offsets for the project at this stage, particularly as some aspects, particularly 'species credit' species abundance and refining Plant Community Types require field validation. The cost to purchase land and required management actions have also not been assessed in detail based on the above. It has, however been demonstrated that there is suitable offset land available in the region to meet the requirements of the project.

Considering the level of existing conservation in the broader Pilliga region is more than 40% of the land area, considering International Union for Conservation of Nature (IUCN) criteria, the desirability of adding an additional 6,408 hectares of native vegetation and corresponding threatened species habitat to the reserve system (either directly or through private land conservation) is questionable. As the majority of species are adversely impacted by feral animals (either through predation, competition or habitat degradation), the use of supplementary measures such as a nil-tenure feral animal control strategy is likely to result in a much greater positive impact on the long term survival of these species than additional land managed for conservation.

3.1.6 'Species credit' species on land-based offset sites

In securing land-based offset sites for 'species credit' species for the project, the Proponent is proposing to use the same methods used to determine impact (i.e. modelling) contained in the Environmental Impact Statement to determine the number of individuals of each 'species credit' flora species present on an offset site. The presence of the species on an offset site will be determined first, followed by an assessment of the presence of suitable habitat, followed by a modelled estimate of individuals present.

For 'species credit' fauna species, the Proponent is proposing to identify suitable potential habitat (as defined through Plant Community Type associations contained in the Threatened Species Profile Database) on offset sites, rather than specifically identifying and mapping individual areas of habitat for these species. The presence of species on an offset site will firstly be inferred based on existing records on or in the vicinity of the offset site and based on the known habitat associations, followed by an estimate of habitat present. This methodology has been proposed due to the conservative assessment of impacts on these species.

Surveys and modelling undertaken for the project were generally undertaken during exceptional seasonal conditions and resulted in the observation of a large number of previously undetected threatened species within the study area.

Considering the 'like for like' nature of the Plant Community Types to be secured as part of any land-based offset site, as well being secured in the Pilliga Region, it is highly likely that the 'species credit' species impacted on by the project would also be present on proposed land-based offset sites.

In calculating the number of credits generated for 'species credit' species on land-based offset sites, the Proponent is proposing to:

1. Identify suitable habitat as defined through Plant Community Type associations for each species.
2. Justify the presence of each species through the presence of suitable habitat, previous records, or targeted survey.
3. Determine the total number of flora individuals present using the same modelling used to determine the upper disturbance limit.
4. Determine the total area of fauna habitat through mapping of Plant Community Type and habitat associations.

3.2 Supplementary measures

Supplementary measures are measures other than protecting and managing land which result in improvements to biodiversity values. They may include improving existing habitat or reducing threats to individual threatened or migratory species, populations and ecological communities.

Due to the existing threats to biodiversity values in the Pilliga Forest (such as well-established feral animal populations, weed invasion, inappropriate fire regimes and unmanaged vegetation community regrowth), an exclusively land-based offset is likely to be less effective for threatened species conservation than supplementary measures using species-specific recovery actions over large areas.

The supplementary measures identified in this Biodiversity Offset Strategy have been nominated as they are cost-effective and will maximise biodiversity outcomes. Wherever possible, the supplementary measures are accompanied by scientific evidence that the measures are likely to lead to long-term benefits to biodiversity and are in accordance with best practice techniques.

Supplementary measures will be implemented through Planning Agreements which will ensure long-term security of financial contributions and ensure that suitable arrangements are in place for monitoring and reporting on the progress of each measure.

Detailed management plans, cost estimates and preparation of Planning Agreements will be prepared post-approval to the satisfaction of the State and Federal Government agencies.

3.2.1 Species threat analysis

In recognition of the high ecological and landscape value of the Pilliga Forest, over 240,000 ha of conservation reserve have been gazetted under the NSW *National Parks and Wildlife Act 1974* (NPW Act) since the 1960s. The Pilliga Nature Reserve (83,000 ha) was first reserved in 1968. 30 years later, regional assessments of the Brigalow and Nandewar Bioregions (NPWS, 2000) culminated in the NSW Government's decision in 2005 to conserve an additional 160,000 ha of Community Conservation Area (CCA) in the Pilliga Forest under the NSW *Brigalow and Nandewar Community Conservation Area Act 2005* (BNCCA Act). This area focuses on the central, southern and western extents of the Pilliga. Today, approximately half of the Pilliga is now reserved under the NPW Act, with the other half mostly State Forest.

To help inform which recovery actions would be most beneficial, a species threat analysis was undertaken. From this analysis, high priority recovery actions were identified where they are known to have achievable conservation benefits. The analysis highlighted which actions offer the most cost effective means of achieving the greatest benefit for threatened species recovery.

For every threatened flora and fauna species known or considered likely or to have the potential to occur in the study area, the threatened species profile (OEH, 2017A), species profiles and threats database (DotE, 2017) and national or state management plans were reviewed to determine the listed threats to each species and the recommended recovery actions or strategies. Only those threats which could feasibly be mitigated through on-ground management strategies were included.

The threats and management strategies identified fell under common themes, most of which corresponded with key threatening processes listed under either the BC Act or the EPBC Act. For most threats there was a clear corresponding management strategy (e.g. the threat of inappropriate fire regimes can be managed by fire management). The number of threatened species affected by each threat and benefited by the corresponding management action was tabulated (treating flora and fauna separately) in order to elucidate the actions that benefited the greatest number of species (**Appendix B**).

The threatening processes found to impact on the highest number of threatened species in the study area are presented in **Table 10** for fauna and Table 11 for flora, along with the corresponding management action to address each threat. Also included are the listed key threatening processes under BC Act and EPBC Act which correspond to each identified threat.

Note that the two threats ‘grazing pressure’ and ‘feral herbivores’ were combined, since the pressure of feral herbivores leads to increased grazing pressure. This category was again broken down into specific herbivore species to determine where management efforts should be directed. Similarly, the threat of ‘feral predators’ was initially considered as one threat, and then later broken down to examine the impact of individual predator species.

Table 10: Threatening processes – fauna

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: BC Act	Equivalent Key Threatening Processes: EPBC Act
Grazing/ habitat disturbance by herbivores				
Specific threat: Stock / unspecified (42); pigs (6); rabbits (9); goats (7); horses (1) Overall# (43)	75.4%	Feral herbivore control	Predation, habitat degradation, competition and disease transmission by feral pigs (<i>Sus scrofa</i>) Competition and grazing by the feral European rabbit (<i>Oryctolagus cuniculus</i>) Competition and habitat degradation by feral goats (<i>Capra hircus</i>)	Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs Competition and land degradation by rabbits Competition and land degradation by unmanaged goats
Inappropriate fire regimes				
36	63.2%	Fire management	High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition	
Feral predators				
Specific threat: Foxes (27); cats (25); wild dogs (11); rats/mice (3); unspecified (3) Overall* (31)	54.4%	Feral predator control	Predation by the European red fox (<i>Vulpes vulpes</i>) Predation by the feral cat (<i>Felis catus</i>) Predation and hybridisation of feral dogs (<i>Canis lupus familiaris</i>)	Predation by European red fox Predation by feral cats
Weed invasion				
19	35.1%	Weed management	Invasion of native plant communities by African Olive <i>Olea europaea</i> subsp. <i>cuspidata</i>	Loss and degradation of native plant and animal habitat by invasion of

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: BC Act	Equivalent Key Threatening Processes: EPBC Act
			Invasion, establishment and spread of <i>Lantana camara</i> Invasion of native plant communities by exotic perennial grasses Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	escaped garden plants, including aquatic plants.

#Note that these categories are not mutually exclusive and thus the total of all species threatened by feral animals does not equal the sum of those affected by each type of feral animal.

Table 11: Threatening processes – flora

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: BC Act	Equivalent Key Threatening Processes: EPBC Act
Weed invasion				
12	75%	Weed control	<p>Invasion of native plant communities by African Olive <i>Olea europaea</i> subsp. <i>cuspidata</i></p> <p>Invasion, establishment and spread of <i>Lantana camara</i></p> <p>Invasion of native plant communities by exotic perennial grasses</p> <p>Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants</p>	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
Grazing/ habitat disturbance by herbivores				
<p>Specific threat: Stock/ unspecified (10); pigs (5); rabbits (7); goats (5)</p> <p>Overall# (12)</p>	62.5%	Feral herbivore control	<p>Predation, habitat degradation, competition and disease transmission by feral pigs (<i>Sus scrofa</i>)</p> <p>Competition and grazing by the feral European rabbit (<i>Oryctolagus cuniculus</i>)</p> <p>Competition and habitat degradation by feral goats (<i>Capra hircus</i>)</p>	<p>Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs</p> <p>Competition and land degradation by rabbits</p> <p>Competition and land degradation by unmanaged goats</p>
Inappropriate fire regimes				
8	50	Fire management	High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition	

#Note that these categories are not mutually exclusive and thus the total of all species threatened by feral animals does not equal the sum of those affected by each type of feral.

Feral animal control

Feral animal control was identified as the highest (grazing/habitat disturbance) and third highest (feral predators) threat to threatened fauna species. Feral animal control (grazing/habitat disturbance) was the second highest threat to threatened flora species. Control of feral animals is an action that is highly beneficial to a large number of threatened flora and fauna species in the Pilliga.

Recent survey work targeting *Dasyurus maculatus maculatus* (Spotted-tailed Quoll) in the north-east Pilliga Forest identified the following feral animals via remote camera - *Vulpes vulpes* (European Red

Fox), *Felis catus* (Cat), *Sus scrofa* (Pig), *Canis lupus familiaris* (Dog) and *Bos* sp. (Cattle), with feral animals accounting for 36% of all images captured (ELA, 2015). This work has identified a range of feral animals including both herbivores that are likely to be adversely affecting habitat quality and carnivores which are likely to be directly contributing to the decline of threatened species through predation.

Weed control

Weed invasion was identified as a threat to 12 of 16 (75%) threatened flora species and 19 of 57 (33.33%) threatened fauna species. Weed invasion is identified as the threat affecting the greatest number of threatened flora and appropriate management is an action that would be beneficial to a large number of threatened species in the Pilliga Forest.

Surveys in the study area identified 116 weed species which comprises 14% of the flora diversity recorded (ELA, 2015). This list was refined to focus on those species which are of most concern to the study area, due to their abundance, distribution or listed impact on threatened flora or fauna (**Table 12**).

Table 12: Weed species of most concern

Weed group	Species of concern in the study area	Threatened fauna affected (DotE, 2014; OEH, 2015)	Threatened flora affected (DotE, 2014; OEH, 2015)	Location of weeds in study area	Priority areas (OEH, 2011)	
					Reserves	Specific sites
Pasture grasses	<i>Eragrostis curvula</i> (African Lovegrass), <i>Hyparrhenia hirta</i> (Coolatai Grass), <i>Panicum maximum</i> (Green Panic),	Bush Stone-curlew, Speckled Warbler, Hooded Robin, Turquoise Parrot, Barking Owl, Scarlet Robin, Grey-crowned Babbler, Diamond Firetail	<i>Polygala linariifolia</i> , <i>Lepidium monoplocoides</i> , <i>Myriophyllum implicatum</i> , <i>Lepidium aschersonii</i>	Widespread <i>E. curvula</i> abundance observed to be increasing along edge of X-line Road	-	-
Berry-bearing shrubs	<i>Lycium ferocissimum</i> (African Boxthorn)	Scarlet robin, Diamond Firetail	<i>Lepidium aschersonii</i> , <i>Lepidium monoplocoides</i>	Records from the field survey are restricted to the north-western portion of the study area, outside of the Pilliga forests.	Pilliga West State Conservation Area, Pilliga West National Park	Brumby Rd, Gilgais
Noogoora Burr	<i>Xanthium occidentale</i>	-	-	Records from the field survey are in the north-western portion of the study area, outside of the Pilliga forests and along Bohena Creek in the Pilliga forests.	Pilliga National Park, Yarragin National Park, Timallallie National Park	South Yarragin, Wittenbra Springs, Bugaldie Creek

Weed group	Species of concern in the study area	Threatened fauna affected (DotE, 2014; OEH, 2015)	Threatened flora affected (DotE, 2014; OEH, 2015)	Location of weeds in study area	Priority areas (OEH, 2011)	
					Reserves	Specific sites
<i>Opuntia</i> spp.	<i>Opuntia stricta</i> (Prickly Pear), <i>Opuntia aurantiaca</i> (Tiger Pear)	Koala	-	Both species are widespread in the study area.	Pilliga National Park, Pilliga State Conservation Area, Pilliga East State Conservation Area, Timallallie National Park, Pilliga Nature Reserve, Willala Aboriginal Area, Yarragin National Park, Timallallie National Park, Pilliga West State Conservation Area, Pilliga West National Park, Merriwindi State Conservation Area	Talluba Creek, No. 1 break, Delwood Road, Scratch Road, Brumby Road, Willala Knobs, South Yarragin, The Duke, Tinegie Creek, Pilliga to Coonamble Road, Bugaldie Creek
Pasture herbs	<i>Phyla canescens</i> (Lippia)	-	<i>Myriophyllum implicatum</i>	Only recorded at one location, however this location is within 1 km of the <i>M. implicatum</i> record.	-	-

Fire management

Inappropriate fire regimes were identified as the second-highest threat to threatened fauna species in the study region, and the third-highest threat to threatened flora species. Therefore, fire management is one of the management actions which would have the greatest benefit to threatened species.

For the majority of flora and fauna species threatened by inappropriate fire regimes, it is high-frequency fire regimes that are detrimental. High frequency fire can lead to direct mortality, food deprivation, an increase in predation levels on native fauna, a reduction in the availability of critical habitat features such as hollow-bearing trees or an inability to attain a critical lifecycle before the next fire event (Gill & Bradstock, 1992; Gill, 1975; Whelan, 2002). For some species, the suppression of fire is also a threat to their survival (e.g. *Rulingia procumbens*, *Bertya opposens*, *Tylophora linearis*).

3.2.2 Management costs

The estimated state-wide expenditure on weed and feral animal control by the National Parks and Wildlife Service in 2006-2007 was \$18 million (DECC, 2006). This included \$4.5 million for feral animal control programs, \$2.8 million for weed control programs and \$10.7 million for operational costs (e.g. labour and other costs) to implement the programs. Assuming this funding was distributed evenly across the 14 NPWS regions then approximately \$1.3 million would be allocated to the Northern Plains Region (in which the Pilliga is located). The Pilliga agglomeration of reserves (including Warrumbungle National Park) accounts for 34% of the total NPWS estate in the Northern Plains Region, so again assuming funding is allocated proportionally within individual regions, then \$440,000 per annum would be allocated to weed and feral animal control in the Pilliga Forest. As funding is unlikely to be allocated evenly across or within regions, an estimate of \$440,000 per annum for weed and feral animal control in the Pilliga is likely to be overly conservative.

The following sections provide detail on the estimated costs to undertake individual actions such as feral animal control, weed control and prescribed burning as identified in the species threat analysis.

Feral animal control

An integrated feral animal control program would provide substantial cost savings compared with a series of single eradications (Griffiths, 2011). An integrated feral control program would also minimise the potential for unintended consequences of the control of particular feral animal species. For example, targeting foxes and/or wild dogs without also implementing control of feral cats has the potential to lead to an increase in cat numbers, as they are released from predation by the larger feral predators (Algar & Smith, 1998). There may also be a need to implement control of feral grazing animals (e.g. rabbits) if foxes or other feral predators are to be targeted, in order to avoid an increase in the populations which previously would have been suppressed through predation. Equally, controlling feral grazing animals without also controlling feral predators could lead to prey switching by feral predators to native animals (Cupples, Crowther, Story, & Letnic, 2011).

Feral Fox control

Costs of various fox baiting programs throughout Australia were reviewed. Baiting using 1080 is considered to be the only cost-effective broadscale control option for foxes (DEC, 2011). Other methods of fox control, such as trapping, shooting, and baiting with other poisons, are labour intensive and not practical on a large scale, and therefore have not been considered. Costs for aerial and ground baiting vary from \$0.37 to \$1.73/ha. A minimum of two baits per square km is necessary for a fox to detect one bait within three days, but up to five baits per square km is highly recommended to allow for non-target uptake by birds and reptiles (Arid Recovery, 2011). Five fox baits per square kilometre are used by Western Australia's highly effective Western Shield Program (DPAW, 2014). For most areas of Australia,

5-10 baits per square km is considered to be the optimum density for reduction of fox populations (Saunders & Mcleod, 2007).

Quarterly baiting has been found to be necessary to prevent reinvasion of baited areas by foxes in arid South Australia with annual baiting being found to be insufficient (Moseby & Hill, 2011). Fox baiting is also conducted four times a year in the Western Shield Program (DPAW, 2014).

Some research has also been carried out as to the efficacy of different delivery methods of bait. For example, at Yathong Nature Reserve in western New South Wales intensive ground baiting of foxes was found to be ineffective in mitigating the threat of predation by foxes on reintroduced *Leipoa ocellata* (Malleefowl) and *Bettongia penicillata* (Brush-tailed Bettongs), but broad-scale aerial baiting three times a year substantially enhanced malleefowl survival (Wheeler & Priddel, 2009).

Aerial baiting is more cost effective for large areas than ground baiting (Fairbridge & Fisher, 2001; Saunders & Mcleod, 2007), due to the lower labour costs and time involved.

Table 13: Costs for fox baiting programs in various areas of Australia (adjusted to 2014 prices)

Method	Location	Cost per ha (\$)	Details of program	Reference
Aerial baiting	Western Shield program WA (3.5 million ha/year)	0.37	Four times per year, over 3.5 million ha with 800,000 baits (5 per km ² per session) Includes \$200,000 operating expenses equivalent to ~\$0.06/ha (advertising, training, materials and education) Covers fuel and provision of a bombardier.	(Saunders & Mcleod, 2007)
Ground baiting	Central NSW (2,000 ha)	0.60-1.20	Four times per year (one-off treatment costs \$0.15-\$0.30/ha). 3 baits/km ² which are checked every 3-5 days and replaced if taken. Cost varies depending on whether baits are checked and replaced 1-5 times. Includes labour costs, baits, vehicle use.	(Saunders & Mcleod, 2007)
	NSW	1.73	Four times a year. Cost is \$0.94 for once a year	(Saunders & Mcleod, 2007)
	Central Victoria (44,000 ha)	1.02	One-off baiting, 10.5 baits/km ²	(Saunders & Mcleod, 2007)
	Hattah-Kulkyne NP Victoria (28000 ha)	0.89	Continuous baiting throughout year, checked every 3-4 weeks (>0.6 baits/km ²).	(Robley, Wright, Gormley, & Evans, 2008)
Coopracamba NP Victoria (38800 ha)	0.60	Continuous baiting throughout year, checked every 3-4 weeks (<0.2 baits/km ²).		

Method	Location	Cost per ha (\$)	Details of program	Reference
	Grampians NP Victoria (72520 ha)	1.10	Pulse of 6-8 weeks baiting, checked daily, then repeated after several weeks break (0.2-0.6 baits/km ²)	
	Wilsons Promontory NP Victoria (36000 ha)	0.75	Pulse of 6-8 weeks, checked daily, then repeated after several weeks break (0.2-0.6 baits/km ²).	
	Little Desert NP Victoria (47600 ha)	0.22 ¹	October/November to March/April with bait stations checked and baits replaced every three to four weeks (<0.2 baits/km ²).	
	Little Desert NP Victoria (45500 ha)	0.29 ²	October/November to March/April with bait stations checked and baits replaced every three to four weeks (<0.2 baits/km ²).	

Feral cat control

Baiting is widely considered to be the most effective method for controlling feral cats on mainland Australia (Algar, Angus, & Williams, 2007; Algar & Burrows, 2004; DEWHA, 2008; Environment Australia, 1999; Short, Turner, & Risbey, 1997). The feral cat bait Eradecat® developed for the Western Shield program in WA has proven to be highly effective in reducing feral cat numbers, especially in semi-arid and arid areas. The effectiveness of other control techniques, including trapping, shooting and fencing is limited by a significant input cost when implemented over large areas (DPAW, 2013).

The theoretical cost of cat baiting could be calculated by adding the cost of the number of baits required per hectare to the cost of a fox baiting program (particularly because fox baiting should not be implemented without also controlling cats due to the potential impacts of mesopredator release on cat populations).

The cost of Eradecat® baits is currently \$0.3 per bait at today's level of production (Algar & Burrows, 2004). At a minimum, 25 baits per square kilometre (0.25/ha) are required for a cat to detect one bait within three days (Arid Recovery, 2011). The Western Shield program in WA uses 50 feral cat baits per square kilometre (0.5/ha), and baiting is conducted once a year. Using these figures, cat baiting could be integrated into a fox baiting program for an added cost of approximately \$0.15/ha.

Feral pig control

The costs of various feral pig control methods were reviewed. The cost per hectare was not available for several of the control method reviewed and in these cases, the cost per hectare was estimated based on potential pig density per hectare. Costs for aerial and ground baiting vary from \$0.2 to \$2.47/ha while costs for trapping are higher (up to \$15/ha) due to increased labour. Costs for aerial shooting range from \$0.2 to \$7.43/ha. Ground shooting is not generally considered a cost-effective control method due to being labour-intensive (DEC, 2011), however it may be useful as a follow-up method.

Table 14: Comparative costs of feral pig control methods in different habitats

Control method	Habitat/area	Cost per pig (\$)	Cost per ha (\$)	Source
Ground Baiting	Slopes and plains	43.01-117.70	0.65-1.77 ¹	(Turvey, 1978)
	Wetland	13.19	1.94	(Choquenot, McIlroy, & Korn, 1996)
	Dryland	6.31	0.194	(Choquenot et al., 1996)
	Dryland	6.50	0.58	(Korn, 1986)
	Agricultural land (eastern NSW) ²	55	1.07	(Saunders, Kay, & Parker, 1990)
	Arid rangelands (western NSW)	1.67	0.15	(Bryant, Hone, & Robards, 1984)
Aerial baiting	Dry tropical savannah (Qld)	37.19	2.47 ²	(Mitchell & Kanowski, 2003)
Trapping	Slopes, plains, scrub (NSW)	56-106	–	(Turvey, 1978)
Trapping	Dry tropical savannah (Qld)	62.90	14.82 ³	(Mitchell & Kanowski, 2003)
	Alpine forest (Kosciusko NP)	136	1.50 ⁴	(Saunders, Kay, & Nicol, 1993)
Aerial Shooting	Woodland (Western NSW)	112.21	2.09	(Hone, 1983)
	Wetland (Macquarie Marshes NSW)	20.92	7.43	(Bryant et al., 1984)
	Wetland	9.70-30.08	0.49-0.69	(Korn, 1986)
	Dryland	5.65–30.08	0.19-0.29	(Korn, 1986)
	Wetland/ dryland	22.86	1.82	(Saunders & Bryant, 1988)
	Wetland/ woodland	11.22	0.56	(Hone, 1990)
	Rangeland	76	0.30	(Lapidge, Derrick, & Conroy, 2003)
	Dry tropical savannah (Qld)	25.90	1.73 ⁵	(Mitchell & Kanowski, 2003)

¹ Calculated from the upper figure in the range of 0.2-1.5 pigs/km² for semi-arid rangelands in NSW

² Warfarin used

³ Calculated from a pre-baiting pig density estimate of 6.7 pigs/km

⁴ Calculated from a pre-trapping pig density estimate of 10.9 pigs/km

⁵ Calculated from an average pig density estimate of 1.1 pigs/km² for Kosciusko NP

⁶ Calculated from a pre-shooting pig density estimate of 6.7pigs/km

Feral goat control

The costs of various feral goat control methods were reviewed. The cost per hectare was not available for several of the control method reviewed and in these cases, the cost per hectare was estimated based on potential goat density per hectare. Costs for aerial shooting range between \$0.1 to \$3.74/ha, mustering ranges between \$0.58 and \$1.29/ha and trapping ranges between \$0.42 and \$6.32/ha. Ground shooting

is not generally considered a cost-effective control method due to being labour-intensive (DEC, 2011), however it may be useful as a follow-up method.

Table 15: Comparative costs of feral goat control methods in different habitats (adjusted to 2014 prices)

Control Method	Habitat/ area	Cost per goat (\$)	Cost per ha (\$)	Reference
Aerial shooting	Western Australia	-	0.09	(Parkes, Henzell, & Pickles, 1996)
	Gammon Ranges SA	-	0.17	(Naismith, 1992)
	Arkaroola (Flinders Ranges SA)	-	3.74	(Henzell, 1981)
	Coolah Tops NP NSW	18.63-41.04	0.67-1.48 ¹	(Fleming et al., 2002)
Mustering	Coolah Tops NP NSW	27.39-28.35	0.99-1.02 ¹	(Fleming et al., 2002)
	South-western Qld	2.41-5.37 (average 2.92)	0.58-1.29 ²	(Thompson, Riethmuller, Kelly, Boyd-Law, & Miller, 1999)
Trapping at waterpoints	South-western Qld	1.74-5.85 (average 3.15)	0.42-1.40 ²	(Thompson et al., 1999)
	Western CMA NSW	-	6.32 ³	(Grant, 2012)
Ground shooting	Rangelands	774	17.03 ⁴	(Edwards, Clancy, Lee, & McDonnell, 1994)
	Kennedy Range NP WA	14-54	0.22-0.86 ⁵	(DEC, 2011)
	Cape Range NP WA	113-149	1.81-2.38 ⁵	(DEC, 2011)

Feral rabbit control

The costs of various rabbit control methods were reviewed. Trapping is not considered an effective rabbit control technique (Williams, Parer, Coman, Burley, & Braysher, 1995) whilst shooting is time consuming and labour intensive, and is therefore not suitable for broadscale control (DEC, 2011). Fumigation is generally thought unsuitable for large areas as it is high cost and labour-intensive but could be useful in smaller target areas where rabbits are a particular problem, or where a particular threatened species is present.

Costs per hectare for rabbit control vary from \$5 to \$32/ha for warren ripping and fumigation and \$9.55 to \$12.74/ha for poisoning. A cost/benefit analysis for rabbit control methods (Williams et al., 1995) shows that some combinations of treatments achieve a high level of control for little more cost than some single treatments, and at much lower cost per benefit obtained. A combination of poisoning, ripping and fumigation achieved an effectiveness of 99% and the lowest cost/benefit of treatment or combination of

treatments, followed by ripping and fumigation (96% effectiveness), poisoning and ripping (91%), ripping alone (80%), poisoning and fumigation (21%) and poisoning alone (12%).

A conservative estimate of costs of rabbit control could be calculated from the total of the upper range figure for all three treatments per hectare per year, although in reality rabbit management becomes progressively cheaper as repeated maintenance treatments achieve higher levels of control (Williams et al., 1995).

Table 16: Rabbit control options (adjusted to 2014 prices)

Control Method	Cost per ha (\$)	Notes	Frequency treatment required	Reference
Warren ripping	5-25			(DAFF, 2006)
	4.78-31.85	Cost given is for large-scale contracts. The higher figure applies to rocky hills with a high density of warrens.	Depends on soil type- on sandy soils 62% of warrens may be reopened within 6 months vs. 12% in 10 years on heavy soils	(Williams et al., 1995)
Warren fumigation	15.92-31.85	Cost given is for large-scale contracts. Cost varies depending on the density of warrens and the nature of the terrain and vegetation.		(Williams et al., 1995)
Poisoning (Pindone or 1080)	9.55-12.74	Cost given is for large-scale contracts and includes all materials and labour. The cost of poisoning is relatively insensitive to variations in density of rabbits and warrens	1-6 years	(Williams et al., 1995)

Weed control

The cost of broad scale weed control will depend on a number of variables: types of weeds present, type of treatment required (e.g. herbicide application vs. mechanical control), frequency of treatment required, area of infestation, density of infestation and climate and terrain of the area to be treated. As such, it is very difficult to provide even an estimate of the cost of weed control per hectare.

There is little data available pertaining to the amount per hectare spent on weed control by government agencies. Those figures which are available show a vast range in costs; for example, yearly weed control costs are given as \$47/ha for the 7,969 ha Canberra Nature Park, compared with \$1/ha for the 102,862 ha Namadgi National Park (Taylor, 2002). Much of this variability would relate to reserve size (and the resulting differences in edge to area ratio), condition, location, and the amount of funding allocated to

weed control in the management budget, and thus not necessarily a useful basis for calculating the potential costs of weed control across the Pilliga.

Even focussing on the priority weed species identified in **Table 12**, the cost of treatment per hectare shows extreme variability. For example, the cost of controlling Opuntoid cacti species by spraying with herbicides can range from a few hundred dollars to \$8,000 or more per hectare (Lloyd & Reeves, 2014). **Table 17** shows the costs of control per hectare that were able to be obtained for weed species of concern to threatened flora and fauna. Should weed control be identified as a priority supplementary measure, then a detailed weed management plan will be prepared to address the priority weed species across the Pilliga.

Table 17: Approximate costs per hectare for the control of weeds of concern to threatened species occurring in study area

Weed Species	Control method	Cost per ha	Details and location	Reference
African boxthorn	Spraying with herbicides and mechanical excavation of plants	\$130-140	3 year trial of control in remnant vegetation in Murry CMA	(Institute for Land Water and Society, 2007)
Blackberry		\$100-249 chemical costs + >\$500 labour costs Total \$600 - >\$749	Conservation and natural environments NSW	(DPI, 2014)
Coolatai grass	Spraying with glyphosate/ flupropanate	>\$360	Pasture, North West Slopes NSW	(McCormick, L., Lodge, & McGullicke, 2002)
	Flupropanate	<\$100 chemical cost + \$100-249 labour costs Total ~ \$200-349	Roadsides North and Central Coast NSW	(DPI, 2014)
	Spot spraying with glyphosate or flupropanate	\$180- 220	Kwiambal National Park northern NSW	(McCormick et al., 2002)
Lippia		<\$100 chemical costs \$100-249 labour costs	Unimproved grazing areas NSW	(DPI, 2014)
	Spraying with DP-600	\$45 chemical cost only	Grazing land, south-east QLD	(Leigh, C. and Walton, 2004)

Weed Species	Control method	Cost per ha	Details and location	Reference
<i>Opuntia</i> spp.	Spot spraying/ digging out	<\$100 chemical cost + \$100-249 labour costs Total ~\$349	NSW	(DPI, 2014)
	Spraying	\$750-1000	Leander QLD	(Lloyd & Reeves, 2014)
	Spraying (triclopyr, picloram or Access)	Few hundred dollars to >\$8000	Western Australia	(Lloyd & Reeves, 2014)

Prescribed burning

The costs of implementing a prescribed burning regime are extremely variable, as shown in **Table 18**. In most cases the range in costs is largely explained by differences in the size of the areas treated in the burning program. The smaller the area, the greater the cost on a per hectare basis (Scherl, 2005).

The most relevant figures obtained are those for burning specifically for flora and fauna management by Victoria's Department of Sustainability and Environment (Environment and Natural Resources Committee, 2008). The cost of these programs is given as \$30-\$300/ha. However, to provide a more conservative estimate of the potential costs of implementing a prescribed burning regime, it may be necessary to use the highest figure found in the literature: in this case \$1,778/ha for asset protection burning by South Australia's Department of Environment, Water and Natural Resources (Gibson & Pannell, 2014). Should prescribed burning be identified as a priority supplementary measure, then a detailed prescribed burning management plan will be prepared.

Table 18: Costs of prescribed burning in Australia

Location	Purpose of burning	Cost per ha (\$)	Notes on figure given	Reference
Southwest WA	Pre-suppression prescribed burning	\$80	Presumed cost of burning, based on data from WA. 100,000 ha jarrah forest (5% burned per year)	(Florec et al., 2013)
Victoria	Ecological burning for specific flora and fauna management	\$30 - \$300		(Environment and Natural Resources Committee, 2008)
Mt Lofty region SA	Prescribed burning for asset protection (not for ecological improvement)	\$1,778	Figure includes \$416/ha administering the prescribed burning program, \$235 on monitoring and post burn weed management and \$1127 on the implementation of the burn.	(Gibson & Pannell, 2014)
Tasmania	Forestry Tasmania fuel reduction burning	\$60 - \$300 (average \$115)		(Deloitte Access Economics, 2014)

Location	Purpose of burning	Cost per ha (\$)	Notes on figure given	Reference
Australian forested landscapes	Prescribed burning for fuel management	\$7 - \$1,000	Lower figure is for broader forest treatment areas generally greater than 500 ha; upper figure for regions near large urban areas Figures include staff and resourcing costs.	(Scherl, 2005)

3.2.3 Nil-tenure feral animal control strategy

The Proponent has committed to the development of a nil-tenure feral animal control strategy which will be up to one third of the total financial offset liability of the project. The feral animal control strategy will initially focus on the study area (including a 5 – 10 km buffer) and will be implemented over a 20 year period. The strategy will focus efforts heavily in the first couple of years followed by maintenance control for the remaining period.

Consultation with NSW Forestry Corporation, the NSW National Parks and Wildlife Service and private landholders will be held during the preparation of the strategy to identify ways to integrate the feral animal control strategy with other strategies across the Pilliga region.

The nil-tenure feral animal control strategy will address feral animal control at a landscape scale. Given the connectivity of habitat in the study area and Pilliga, it is considered most beneficial to approach feral animal control at this scale.

The strategy will be designed to target feral fauna identified as high risk to the survival of native flora and fauna in the Pilliga. Control measures used will be specific for the target fauna species, with a range of control techniques to be applied. The poisoning of non-target species will be addressed through the design of the control techniques. The strategy will include monitoring to detect changes to targeted feral fauna abundance from control measures applied at the landscape scale. Monitoring will also aim to detect poisoning of non-target species to ensure the program is not having adverse effects on native wildlife.

3.2.4 Compensatory measures

Compensatory measures are other measures (such as funding for research of educational programs) that do not directly offset the impacts on threatened or migratory species, populations or ecological communities, but are anticipated to lead to biodiversity benefits. The proposed compensatory measures directly relate to the conservation of *Phascolarctos cinereus* (Koala) in the Pilliga and will be capped at 10% of the total offset package in accordance with the NSW Biodiversity Offset Policy for Major Projects. Based on the likely total financial offset liability of the project, the Koala research proposal is likely to contribute less than 10% of the overall offset package.

Koala research proposal

In recent years there has been a dramatic decline in Koala numbers inhabiting the Pilliga. Recent studies (ELA, 2015; Niche Environment and Heritage, 2014) failed to locate Koalas within the study area, however isolated remnant populations have been detected in the western Pilliga (Niche Environment and Heritage, 2014). More recent studies have identified Koala within the north-west of the study area. Given the decline in the Pilliga Koala population, a research proposal from Dr Stephen Phillips (an internationally acknowledged authority on Koalas) has been prepared which aims to provide the best value for money

in determining the precise location and sizes of remnant Koala populations in the broader Pilliga region to inform conservation efforts for the important population of this species. The detailed Koala research proposal is included in **Appendix C** with a brief summary provided below.

This method proposed includes establishing a 500 m survey grid across the entire 500,000 ha of Pilliga with the intent to establish a permanently fixed grid that can be surveyed at varying scales, initially at 8 km sampling intersections in order to provide an unbiased occupancy estimate. At this scale of sampling approximately 120 primary field sites would be involved.

Working off the same grid but at a finer resolution of sampling (i.e. 250 m - 500 m intervals) in areas where remnant populations have been detected or are otherwise known to occur, a Koala meta-population model would be prepared that delineates the precise areas being utilized by resident populations with a view to enabling a focusing of management/recovery effort on such issues as weed control, fire suppression and other threatening processes. The models will be accompanied by robust Koala density estimates with the actual number of animals comprising the relic population cell precisely identified with 95% confidence.

In order to demonstrate the outcome and potential of this approach, at least two localities where Koalas were detected during the 2013 –2014 survey program (Niche Environment and Heritage, 2014) will be specifically targeted. Other localities may also be considered. All grid points once sampled have utility for longer-term monitoring biodiversity and koala population monitoring purposes.

Additional funding would be sought to capture additional population cells following completion of this project and/or government/community/industry staff could be trained in the technique with a view to developing a program of ongoing assessment and monitoring.

3.3 Indigenous cultural heritage values and activities

As identified in **Section 2.5**, consideration of Aboriginal cultural heritage values is a key component of the Biodiversity Offset Strategy and Biodiversity Offset Package. Cultural heritage values will be identified and integrated into biodiversity offsets in three ways:

- Aboriginal cultural heritage values such as important sites, places of traditional or recent significance and culturally important plants and animals will be identified as part of the selection of suitable land-based biodiversity offsets.
- Community access to biodiversity offset areas will be facilitated where practicable.
- Community management of offset lands will be encouraged.

3.4 Biodiversity Conservation Fund or bond

Once land-based offsets and supplementary measures have been finalised, the remaining offset liability for the project will be held for eventual transfer into the Biodiversity Conservation Fund (once operational).

The precise mechanism for holding the financial offset liability until the establishment of the Biodiversity Conservation Fund is yet to be determined, but may include preparation of a Planning Agreement or bond.

The Biodiversity Conservation Fund will then be used by the fund program manager (NSW Biodiversity Conservation Trust) to meet the remaining liability of the project to ensure the 'like for like' conservation of biodiversity values impacted in the study area.

4 Statement of commitments

This Biodiversity Offset Strategy is the Proponents' commitment to adequately offset the residual impacts of the project following implementation of avoidance, minimisation and mitigation strategies. The Biodiversity Offset Strategy ensures that long-term conservation outcomes are achieved in recognition of the *NSW Offsetting Principles* and the *NSW Biodiversity Offset Policy for Major Projects*. The ecological impact assessment of the project determined that there would be no significant impact to MNES, therefore offsets for MNES are not required under the EPBC Act Offset Policy, however as the *NSW Biodiversity Offset Policy for Major Projects* and *Framework for Biodiversity Assessment* apply to the project, MNES will be directly and indirectly offset as part of this Biodiversity Offset Strategy.

In line with the contents of this Biodiversity Offset Strategy, the Proponent will:

- Commit to delivering biodiversity offsets which meets the offset quantum determined by the Framework for Biodiversity Assessment, including the development of an offset package which includes a combination of:
 - Like-for-like offsets secured via an appropriate conservation mechanism.
 - Supplementary measures developed and funded through Planning Agreements.
 - Compensatory measures including Koala research.
 - NSW Biodiversity Conservation Fund will be used for remaining offset liability (when established).
- Identify cultural heritage values as part of the Biodiversity Offset Package, including:
 - Incorporation of Aboriginal cultural heritage values in land-based offset sites.
 - Community access to biodiversity offsets.
 - Community management of land-based offsets.
- Prepare a Biodiversity Offset Management Plan that clearly outlines the responsible parties for the implementation of the plan, the works required to improve biodiversity values (may include but not restricted to fire management, weed and feral animal control, erosion and sediment control, restrictions on access, revegetation), performance criteria and a reporting and monitoring program in accordance with the Biodiversity Assessment Methodology.
- Prepare a nil-tenure feral animal control strategy which will be approximately equivalent to up to one third of the total offset liability of the project which will address feral animal control at a landscape scale.
- Undertake reporting for land-based offsets owned and managed by the Proponent in accordance with the Biodiversity Assessment Methodology.
- Undertake a periodic review of the Biodiversity Offset Management Plan every 5 years in accordance with the Biodiversity Assessment Methodology.

References

- ACT Government. (1999a). *Hooded Robin (Melanodryas cucullata): A vulnerable species. Action Plan No. 15.* (Vol. 1997). Canberra.
- ACT Government. (1999b). *Regent Honeyeater (Xanthomyza phrygia): An endangered species. Action Plan No. 20.* (Vol. 1997). Canberra.
- ACT Government. (1999c). Superb Parrot *Polytelis swainsonii* - Action Plan No. 17. (W. R. and Monitoring, Ed.).
- ACT Government. (2005). Spotted-tailed Quoll (*Dasyurus maculatus*) - a vulnerable species. 30. Retrieved from http://www.environment.act.gov.au/cpr/conservation_and_ecological_communities/threatened_species_action_plans
- Algar, D., Angus, G., & Williams, M. (2007). Influence of bait type, weather and prey abundance on bait uptake by feral cats (*Felis catus*) on Peron Peninsula, Western Australia. *Conservation Science Western Australia*, 6(1), 109–149.
- Algar, D., & Burrows, N. . (2004). A review of Western Shield: feral cat control research. *Conservation Science Western Australia*, 5(2), 131–163.
- Algar, D., & Smith, R. (1998). Approaching Eden. *Landscape*, 13, 28–34.
- Arid Recovery. (2011). *Feral facts: A resource for landholders*. Retrieved from www.aridrecovery.org.au
- Attwood, S. J., Park, S. E., Maron, M., Collard, S. J., Robinson, D., Reardon-Smith, K. M., & Cockfield, G. (2009). Declining birds in Australian agricultural landscapes may benefit from aspects of the European agri-environment model. *Biological Conservation*, 142, 1981–1991.
- Baker-Gabb, D. (2011). *National Recovery Plan for the Superb Parrot Polytelis swainsonii*. Melbourne.
- Bryant, H., Hone, J., & Robards, G. . (1984). *Technical Bulletin 30: The evaluation of a pilot scheme to control feral pigs in north-west NSW*. Department of Agriculture NSW, Trangie.
- Carter, O. (2010). *National Recovery Plan for the Spiny Peppercreess Lepidium aschersonii*. Melbourne.
- Choquenot, D., Mcllroy, J., & Korn, T. (1996). *Managing Vertebrate Pests: Feral Pigs*. Bureau of Rural Sciences, Australian Government Publishing Service, Canberra.
- CQCHM. (2014). *Culturally important food plants*. Prepared for Santos NSW (Eastern) Pty Ltd.
- Cupples, J. B., Crowther, M. S., Story, G., & Letnic, M. (2011). Dietary overlap and prey selectivity among sympatric carnivores: could dingoes suppress foxes through competition for prey? *Journal of Mammalogy*, 92(3), 590–600.
- DAFF. (2006). *Australia's pest animals: New approaches to old problems - Science for decision-makers*. Retrieved from <http://www.acera.unimelb.edu.au/materials/brochures/SDM-AustraliasPestAnimals.pdf>
- DEC. (2006a). Recovery Plan for the Bush Stone-curlew *Burhinus grallarius*. (N. S. W. D. of E. and Conservation, Ed.). NSW Department of Environment and Conservation.

- DEC. (2006b). Recovery Plan for the Large Forest Owls. (N. S. W. D. of E. and Conservation, Ed.). NSW Department of Environment and Conservation.
- DEC. (2011). *Efficiency of the Department of Environment and Conservation's aerial pest management programs on former pastoral leases*. Department of Environment and Conservation Western Australia. Retrieved from http://www.dec.wa.gov.au/publications/doc_download/5415-efficiency-of-dec-s-aerial-pest-management-programs-on-former-pastoral-leases.html
- DECC. (2006). *Protecting our National Parks from Pests and Weeds*.
- DECC. (2008). Recovery plan for the koala (*Phascolarctos cinereus*). Sydney, NSW: NSW Department of Environment and Climate Change.
- DECCW. (1999). *Northern Rivers Regional Biodiversity Management Plan*. Department of Environment, Climate Change and Water.
- DECCW. (2010). *Border Ranges Rainforest Biodiversity Management Plan NSW & QLD*. NSW Department of Environment, Climate Change and Water.
- Deloitte Access Economics. (2014). *Scoping Study on a Cost Benefit Analysis of Bushfire Mitigation. Report for the Australian Forest Products Association*. Retrieved from <http://www.ausfpa.com.au/wp-content/uploads/AFPDAE-report-Amended-Final-2014-05-27.pdf>
- DEWHA. (2008). Threat Abatement Plan for predation by feral cats. (W. Department of the Environment Heritage and the Arts, Ed.). Australian Government Department of Environment, Water, Heritage and the Arts.
- DotE. (2017). Species Profile and Threats Database. Retrieved from [Http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl](http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl)
- DPAW. (2013). *Fortescue Marsh Feral Cat Baiting Program (Christmas Creek Water Management Scheme) Year 2 Annual Report*. Department of Parks and Wildlife, Western Australia. Retrieved from <http://www.fmgf.com.au/UserDir/FMGRReports/Documents/CC-RP-EN-0068212.pdf>.
- DPAW. (2014). *Managing the threats*. Department of Parks and Wildlife, Western Australia. Retrieved from <http://www.dpaw.wa.gov.au/management/pests-diseases/westernshield/189-managing-the-threats>
- DPI. (2014). *NSW Weed Risk Management Assessments*. NSW Department of Primary Industries. Retrieved from <http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/wrm-system>.
- DSE. (2001). *Grey-crowned Babbler, Pomatostomus temporalis: Action Statement No. 34*.
- DSE. (2003a). *Flora and Fauna Guarantee Action Statement 193 - Painted Honeyeater Grantiella picta*. Retrieved from http://www.dse.vic.gov.au/__data/assets/pdf_file/0017/103175/193_Painted_Honeyeater_2003.pdf
- DSE. (2003b). *Flora and Fauna Guarantee Action Statement 199 - Brolga Grus rubicunda*. Retrieved from http://www.dse.vic.gov.au/__data/assets/pdf_file/0011/103160/119_Brolga_2001.pdf
- DSE. (2003c). *Flora and Fauna Guarantee Action Statement No. 124 - Masked Owl Tyto novaehollandiae novaehollandiae*.
- DSE. (2004). *Flora and Fauna Guarantee Action Statement 166 - Squirrel Glider Petaurus norfolcensis*.

- DSEWPaC. (2012). *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy*. Canberra.
- Edwards, G., Clancy, T., Lee, J., & McDonnell, J. (1994). *Feral animal control in the rangelands, final report to the Australia Nature Conservation Agency*. Canberra.
- ELA. (2015). *Narrabri Gas Project - Ecological Impact Assessment*. Prepared for Santos NSW (Eastern) Pty Ltd.
- Environment and Natural Resources Committee. (2008). *Report of the Natural Resources Committee on the inquiry into the impact of public land management practices on bushfires in Victoria. Parliamentary paper*. Retrieved from http://www.parliament.vic.gov.au/images/stories/committees/enrc/bushfire_inquiry/Final_Report/FINAL_for_web_v2.pdf
- Environment Australia. (1999). *Threat Abatement Plan for Predation by Feral Cats*. Environment Australia, Biodiversity Group, Canberra.
- Fairbridge, D., & Fisher, P. (2001). Keeping predator control programs on target: field assessment of bait uptake by target and non target species in Victoria. In *Proceedings 12th Australasian Vertebrate Pest Conference, Melbourne* (pp. 17–21). Department of Natural Resources and Environment, Victoria.
- Fleming, P., Tracey, J., Jones, G., England, K., Leeson, M., & Martin, M. (2002). *The costs of methods for reducing feral goat abundance at a high density site*. Orange, NSW Agriculture.
- Florec, V., Pannell, D., Burton, M., Kelson, J., Mellor, D., & Milne, G. (2013). Economic analysis of bushfire management programs: a Western Australian perspective. In *Proceedings of Bushfire CRC and AFAC 2012 Conference Research Forum, 28 August 2012*. Perth, Australia: Bushfire CRC.
- GHD. (2015). *Narrabri Gas Project –Environmental Impact Statement. Prepared for Santos NSW (Eastern) Pty Ltd*.
- Gibson, F. L., & Pannell, D. J. (2014). *Integrated economic assessment of fire risk management strategies: case studies in central Otago, New Zealand, and Mount Lofty region, South Australia*.
- Gill, A. . (1975). "Fire and the Australian flora: a review." *Australian Forestry*, 38, 4–25.
- Gill, A. ., & Bradstock, R. . (1992). A national register for the fire response of plant species. *Cunninghamia*, 2, 653–660.
- Grant, R. (2012). *Feral Goat Management to achieve Healthy Groundcover: Discussion Paper*. Western Catchment Management Authority. Retrieved from http://archive.ils.nsw.gov.au/__data/assets/pdf_file/0006/496653/archive-feral-goat-management-to-achieve-healthy-groundcover-discussion-paper.pdf
- Griffiths, R. (2011). *Targeting multiple species—A more efficient approach to pest eradication in Island Invasives: Eradication and Management*. (C. Veitch, M. Clout, & TownsDR, Eds.). International Union for Conservation of Nature.
- Henzell, R. P. (1981). *Technical notes on the shooting of feral goats on Arkaroola from 1-5 June, 1981*. Animal and Plant Control Commission, Adelaide.
- Hone, J. (1983). A Short-Term Evaluation of Feral Pig Eradication at Willandra in Western New South Wales. *Australian Wildlife Research*, 10, 123–130.

- Hone, J. (1990). Predator Prey Theory and Feral Pig Control, With Emphasis on Evaluation of Shooting From a Helicopter. *Australian Wildlife Research*, 17, 123–130.
- Institute for Land Water and Society. (2007). *Review of the Murray Catchment Management Authority's trial project – Control of African boxthorn within remnant vegetation*. Institute for Land, Water and Society, Charles Sturt University. Retrieved from http://www.csu.edu.au/__data/assets/pdf_file/0007/702934/37-African-boxthorn.pdf
- Kavanagh, R. P., & Stanton, M. A. (2005). Vertebrate species assemblages and species sensitivity to logging in the forests of north-eastern New South Wales. *Forest Ecology and Management*, 209, 309–341.
- Korn, T. J. (1986). The use of helicopters for feral pig control in New South Wales. In *10th National Conference of Noxious Plants and Animals*. Port Stephens, New South Wales.
- Lapidge, S. J., Derrick, M., & Conroy, J. (2003). Adaptive management and demography of feral pigs in southern Queensland. In *Proceedings of the Feral Pig Action Agenda*. Australian Capital Territory, Australia: Pest Animal Control CRC.
- Leigh, C. and Walton, C. S. (2004). *Lippia (Phyla canescens) in Queensland*.
- Lloyd, S., & Reeves, A. (2014). *Situation Statement on Opuntoid Cacti (Austrocylindropuntia spp., Cylindropuntia spp. and Opuntia spp.) in Western Australia*. Invasive Species Program, DAFWA.
- Mavromihalis, J. (2010). *National Recovery Plan for the Winged Peppergrass Lepidium monoplocoides*. Melbourne.
- McCormick, L., Lodge, G., & McGullicke, B. (2002). *Management of Coolatai Grass on the North western Slopes of New South Wales*. *Meat & Livestock Australia*. Department of Agriculture, Sydney. Retrieved from <http://www.dpi.nsw.gov.au/agriculture/field-crops-pastures/pastures/species-varieties/coolatai>
- Mitchell, J. L., & Kanowski, A. (2003). *Best Practice Feral Pig Management in the Burdekin River Catchment*. Report to National Feral Animal Control Program, Bureau of Rural Sciences.
- Moseby, K. E., & Hill, B. M. (2011). The use of poison baits to control feral cats and red foxes in arid South Australia I. Aerial baiting trials. *Wildlife Research*, 38, 338–349.
- Naismith, T. (1992). Feral goat control in national parks in the Flinders and Gammon Ranges. In L. W. Best (Ed.), *Feral Goat Seminar: Proceedings*. Department of Environment and Planning, Adelaide.
- Niche Environment and Heritage. (2014). *Koala refuges in the Pilliga Forests. Prepared for Eco Logical Australia and Santos*.
- NPWS. (2000). Brigalow Belt South: Regional Assessment (Stage 1) Report on Preliminary Fauna Survey of Pilliga and Goonoo Forests, November 1999 to January 2000. (N. S. W. N. P. and W. Service, Ed.).
- NPWS. (2003). *Draft Recovery Plan for Barking Owl, Ninox connivens*. (N. P. and W. Service, Ed.). Sydney.
- NSW Scientific Committee. (2008a). *Hooded Robin Melanodryas cucullata cucullata – Populations in Eastern Bioregions. Review of current information in NSW. May 2008. Unpublished report arising from the Review of the Schedules of the Threatened Species Conservation Act 1995*. Hurstville.

- NSW Scientific Committee. (2008b). *Squirrel Glider Petaurus norfolcensis Review of current information in NSW. August 2008. Unpublished report arising from the Review of the Schedules of the Threatened Species Conservation Act 1995.* Hurstville.
- NSW Scientific Committee. (2008c). *Tylophora linearis P.I.Forst (Apocynaceae) - Review of Current information in NSW* (June.).
- NSW Scientific Committee. (2013). NSW Scientific Committee: Final determination. Black Falcon.
- OEH. (2011). Draft Northern Plains Regional Pest Management Strategy Party B: 2012-2015. Sydney South, NSW 1232: NSW Office of Environment and Heritage.
- OEH. (2014a). NSW Biodiversity Offsets Policy for Major Projects.
- OEH. (2014b). OEH principles for the use of biodiversity offsets in NSW. Retrieved from <http://www.environment.nsw.gov.au/biodivoffsets/oehoffsetprincip.htm>
- OEH. (2015a). Border Rivers Gwydir / Namoi Regional Native Vegetation PCT Map Version 1.0. VIS_ID 4467, NSW Office of Environment and Heritage, Sydney, Australia.
- OEH. (2015b). Central West / Lachlan Regional Native Vegetation PCT Map Version 1.0. VIS_ID 4468, NSW Office of Environment and Heritage, Sydney, Australia.
- OEH. (2017a). Threatened Species Profiles. NSW Office of Environment and Heritage. Retrieved from http://threatenedspecies.environment.nsw.gov.au/tsprofile/browse_scientificname.aspx
- OEH. (2017b). NSW BioNet Atlas of NSW Wildlife [Web Page]. Retrieved January 21, 2016, from <http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas.watlas.jsp>
- Parkes, J., Henzell, R., & Pickles, G. (1996). *Managing vertebrate pests: feral goats.* Canberra, AGPS.
- QLD EPA. (2008). *Regent honeyeater Xanthomyza phrygia Conservation Management Profile.* Queensland Environment Protection Agency.
- Robley, A., Wright, J., Gormley, A., & Evans, I. (2008). *Adaptive Experimental Management of Foxes. Final Report.* Parks Victoria Technical Series No. 59. Parks Victoria, Melbourne.
- Saunders, G., & Bryant, H. (1988). The Evaluation of a Feral Pig Eradication Program During a Simulated Exotic Disease Outbreak. *Australian Wildlife Research*, 15, 73–81.
- Saunders, G., Kay, B., & Nicol, H. (1993). Factors Affecting Bait Uptake and Trapping Success for Feral Pigs (*Sus Scrofa*) in Kosciusko National Park. *Wildlife Research*, 20, 653–665.
- Saunders, G., Kay, B., & Parker, B. (1990). Evaluation of a warfarin poisoning campaign for feral pigs (*Sus scrofa*). *Australian Wildlife Research*, 17, 525–533.
- Saunders, G., & Mcleod, L. (2007). *Improving fox management strategies in Australia.* Bureau of Rural Sciences, Canberra. Retrieved from http://www.feral.org.au/wp-content/uploads/2010/03/final.proof_fox_collated_book.low.res.pdf
- Scherl, T. (2005). *At the Crossroads: A Comparison of Current Social, Scientific and Political Influences on Fire Management in Australia and the USA.* Portland Oregon USA.
- Short, J., Turner, B., & Risbey, D. (1997). Control of feral cats for nature conservation. *Wildlife Research*, 24, 703–714.

- Swift Parrot Recovery Team. (2011). *National Recovery Plan for the Swift Parrot Lathamus discolor*. Melbourne.
- Taylor, S. (2002). Invasive weed control in grassy ecosystems. In *ecosystemsEighteenth Australasian Weeds Conference*. Retrieved from <http://www.caws.org.au/awc/2012/awc201210781.pdf>
- Thompson, J., Riethmuller, J., Kelly, D., Boyd-Law, S., & Miller, E. (1999). *Feral goat management in South-West Queensland -Final Report to the Bureau of Rural Sciences*. Queensland Department of Natural Resources and Mines, Brisbane.
- TSC. (2008). *Approved Conservation Advice for Tylophora linearis*. Retrieved from <http://www.environment.gov.au/biodiversity/threatened/species/pubs/55231-conservation-advice.pdf>
- TSSC. (2004). *Commonwealth Listing Advice on Dasyurus maculatus maculatus (Spot-tailed Quoll, Spotted-tailed Quoll, Tiger Quoll)*. Threatened Species Scientific Committee, Canberra. Retrieved from <http://www.environment.gov.au/biodiversity/threatened/species/tiger-quoll.html>
- Turvey, R. (1978). *Approaches to the selection of optimal control strategies for feral pigs: cost-effectiveness analysis of present control methods*. University of New England, Armidale.
- Wheeler, R., & Priddel, D. (2009). The impact of introduced predators on two threatened prey species: a case study from western New South Wales. *Ecological Management and Restoration*, 10, 117–123.
- Whelan, R. J. (2002). Managing Fire Regimes for Conservation and Property Protection: an Australian Response. *Conservation Biology*, 16(6), 1659–1661.
- Williams, C. K., Parer, I., Coman, B. J., Burley, J., & Braysher, M. L. (1995). *Managing Vertebrate Pests: Rabbits*. Canberra.
- Woinarski, J. C. Z., Burbidge, A. A., & Harrison, P. L. (2014). *The action plan for Australian mammals 2012*. Collingwood, Victoria: CSIRO Publishing.

Appendix A Culturally important food plants

Scientific Name	Common Name/s	Use
<i>Acacia farnesiana</i>	Prickly moses, prickly mimosa, north-west curara, sponge wattle, cassy, sheep's briar, thorny acacia, thorny feather-wattle	The pods from the mimosa bush were once sucked and the seeds eaten raw as though they were green beans. The thorns were used to pick out splinters.
<i>Ajuga australis</i>	Austral bungle	This plant was used to bathe sores and boils. Fresh leaves were bruised and soaked in hot water to create the infusion. Leaves were also placed in shoes to remove bad odours
<i>Allocasuarina diminuta</i>	Drooping sheoak	Leaves and young cones were chewed raw to quench thirst. Ngarrindjeri people of the lower Murray River made shields, clubs and boomerangs from the hard wood. As a main source of food for Glossy Black Cockatoos, areas where these plants are common were used to hunt birds. Archaeologists found a boomerang 10,000 years old made from sheoak wood in Wylie Swamp, South Australia.
<i>Alphitonia excelsa</i>	Shampoo tree, soap tree, red ash	The leaves from the red ash are used very similarly to soap and having much of the same effect. The young leaf tips were chewed for an upset stomach and a decoction of bark and wood was used as a liniment for muscular pains or gargled to relieve toothache. Commonly used as a fish poison, crushed leaves and berries were placed in water, the plant contains saponin, which removes oxygen from the water, causing the fish to flounder to the surface. The water is then undrinkable, usually done towards the end of the dry season or in an emergency.
<i>Alstonia constricta</i>	Quinine tree, quinine, bitter-bark, fever-bark, peruvian bark	Latex from the quinine bush was used to cure infectious sores, though rather harsh on the skin and considered poisonous. Also said to assist in the case of diabetes and blindness
<i>Amyema miquelii</i>	Drooping mistletoe, stalked mistletoe, snotty gobblers, boxed mistletoe	Edible fruit, Mrs Jean Hamilton grew up at Cuttabri and around Pilliga and she remembers collecting snottygobblers from different trees. Mr Dan Trindall and Mrs Delma Brennan during the oral histories told how they used to get snottygobblers off the vines on horseback, it made

Scientific Name	Common Name/s	Use
		it easy to reach the fruit off the horses. Delma described snottygobbles as a thing that was full of moisture
<i>Astrebala pectinata</i>	Barley mitchell grass, cow mitchell	The seeds were gathered, ground and made into damper. Aboriginal seed grinding dishes are a reminder of the important usage of grasses
<i>Astroloma humifusum</i>	Cranberry heath, Fiery hogs, native cranberry	The sweet edible berries from the native cranberry were eaten. During the oral histories Mervyn Cain and Maureen Sulter told how as children they would collect fiery hogs at Burra Bee Dee
<i>Banksia marginata</i>	Silver banksia, warrock, dwarf honeysuckle	The flower-cones are soaked in wooden or bark containers with water, the liquid turns sweet from the nectar then is ready for drinking or the nectar may be sucked directly from the flower. Victorian Aborigines used the dried flowers from the Banksia as strainers for drinking water.
<i>Brachychiton populneus</i>	Black Kurrajong, common kurrajong	The pods contain edible seeds, which are collected and in most cases roasted. Mr Brad Sulter while on a bush tucker survey conducted in Coonabarabran spoke of a drink made from the crushed seeds that is quite like coffee. During the oral histories Mrs Delma Brennan from Narrabri talked about how when she was a kid they used to collect and eat the seeds. She was taught never to eat them green but only when the pod had cracked. Delma also made little birds out of the pods as toys sitting around the camp with the other children. Roots once were tapped for water in times of drought, the young roots are eaten as well as the gum produced on the tree. Mrs Maureen Sulter from Coonabarabran told how dilly bags were made from the inner bark. Fish and bird nets and net bags were also made from the fibrous bark.
<i>Calandrinia eremaea</i>	Parakeelya	The leaves were an important food source to Aborigines and were eaten as greens or as a thirst quencher. The seeds are also useful as they could be grounded up into a past eaten raw or cooked

Scientific Name	Common Name/s	Use
<i>Callitris glaucophylla</i>	Murray pine, white pine, cypress pine, native pine	The fresh needle leaves are used as a 'washing' medicine for the treatment of sores and scabies; the leaves are ground quite finely with a stone and boiled in water. It can also be rubbed on the chest to relive coughing, rather like Vicks Vaporub. When used as a smoking medicine, a hole is dug and filled with leafy branches, which smoke profusely when lit. The sick person stands over the hole in the smoke and the sickness comes out with the sweat, leaving them feeling strong. The resin from <i>Callitris</i> species was used as a type of glue for fastening barbs to reed spears and axe-heads to handles, fish spears were also made from the long branches.
<i>Capparis lasiantha</i>	Nipan, slip-jack, maypan, honeysuckle, napan, nepine	For coughs honey is used from the flowers. For the relief of swellings, snake bites, insect bites and stings, the whole plant including the roots is mixed up with water then applied to the affected area. The unripe fruit were picked and placed in sand to ripen away from ants. During the oral histories Mrs Jean Hamilton spoke of plants kids used to eat growing up in Cuttabri and around Pilliga and napans were one of the plants that Jean had mentioned. Mrs Thelma Leonard from Minnom Mission at Pilliga described the napans as being egg shaped but only tiny, they start out green then turn yellow like a banana when ready to be picked
<i>Capparis mitchellii</i>	Bimbi, bumbil, native pomegranate, native orange, bumble tree, mondo, karn-doo-thal, small native pomegranate	The fruit is filled with a brightly coloured orange pulp, which is eaten raw and the taste is very sweet. The seeds inside the pulp can be ingested and are best to be swallowed without chewing. This fruit is still a favourite bush tucker today providing moderate energy, water, and carbohydrates. It is a good source of vitamin C and thiamine. Mrs Jean Hamilton spoke of growing up at Cuttabri and around the Pilliga and she remembers going out and collecting the bumble fruit. Mrs Thelma Leonard also spoke of the old bumble tree she was taught about as a child on Minnom Mission at Pilliga. Mrs Mavis Dennison grew up at Old Toomelah and she described the bumble like an apple or orange and very tasty.
<i>Cassytha glabella</i>	Slender dodder-laurel, tangled dodder-laurel, dodder, devil's twine	The small fruits are edible but resinous. The flesh surrounding the central stone is said to taste very aromatic and tangy.

Scientific Name	Common Name/s	Use
<i>Centipeda cunninghamii</i>	Scent weed, old mans weed, common sneeze weed	Webb (1948) notes that this species has been used to alleviate cases of sandy blight (inflammation of the eyes) in humans. Boiling the plant in water creates a black liquid this substance can be either drunk for tuberculosis or used as a lotion for skin infections
<i>Chenopodium cristatum</i>	Crested crumbweed, crested goose float	Poultice of leaf and stem were applied for septic inflammation and breast abscess
<i>Citrullus colocynthis</i>	Colocynth, paddymelon	Although this plant species is poisonous in some regions the juice from the melon is heated and once warm, rubbed onto skin infections such as ringworm and scabies
<i>Dodonaea viscosa</i>	Giant hopbush, watchupga, switch-sorrel, sticky hopbush, akeake, apiri, hopbush	Cochrane <i>et al.</i> (1968) recorded that Aborigines used the wood of larger plants for making clubs. For toothaches and cuts, the boiled roots or juice of roots was applied. Hopbush was burnt to smoke newborn babies. On the coast the chewed leaf and juice was used for stonefish and stingray stings. The juice was placed directly on the sting and bound up for 4-5 days.
<i>Enchylaena tomentosa</i>	Creeping saltbush, Barrier saltbush, plum puddings, berry cottonbush, ruby saltbush	The juicy sweet tasting berries from the salt bush were eaten they contained a small black seed, which was also eaten. The young leaves, which are quite fleshy, were boiled and eaten like vegetables. Soaking the fruits in water made a drink. The fruit was also used as a red dye
<i>Eucalyptus camaldulensis</i>	Red river gum, flooded gum, forest gum, yarrah, biall, creek gum, blue gum, Murray red gum, river gum	River red gums offer a powerful antiseptic. The dark inner bark is boiled until the red gum comes out, when cool it is used as a rubbing medicine for sores such as scabies. For children with diarrhoea the heartwood is boiled in water, then drunk. The seeds are edible and can be ground to make damper. Also used for the treatment of burns. The bark from the river red gum was commonly used to make canoes. On some old 'canoe trees' the scars are still present to this day

Scientific Name	Common Name/s	Use
<i>Eucalyptus populnea</i>	Popular box, round-leaf box, bimble box, red box, bimble, white box, egolla, nankeen gum, round-leaved box, shiny-leaf box, popular-leaved box	The roots were tapped for water
<i>Exocarpos cupressiformis</i>	Wild cherry, cherry ballart, native cherry.	The sap was applied from the native cherry as a cure for snakebites and the wood was used for making spears, spearthrowers and bull-roarers (a ceremonial instrument). Edible juicy fruits are also produced on the tree. In Gamilaraay country, trees in this family are used for smoking for protection
<i>Flindersia maculosa</i>	Spotted tree, spotted dog, leopard tree	This tree produces a good quality gum used for sticking things together. During the summer large masses of clear amber-coloured residue come from the stem & branches, it has a pleasant taste and forms a very common bushman's remedy for diarrhoea
<i>Geijera parviflora</i>	Australian willow, dogbush, sheep bush, gingerah, wilga	For relief of pain an infusion of leaves has been used internally as well as externally. Wilga leaves are used for toothaches, chewed leaves are placed into the cavities. This method alleviates the pain. When used for ceremonial purposes leaves are baked, powdered and smoked in sequence with other narcotic plants this mixture induces drowsiness and drunkenness. Wilga makes an excellent windbreak and provides good shelter
<i>Grevillea striata</i>	Western beefwood, beef oak, beef silky oak, silvery honeysuckle	The sap is scrapped from the damaged beefwood tree then grated into powder and sprinkled on sores, burns and cuts. It is said to dry them out and cause them to heal rapidly. Mixing the grated sap with charcoal from the beefwood and stuffing it into wounds is used to stop bleeding and promote healing. The beefwood provides a dark-reddish resinous exudate from the trunk and from the roots, this is used as cementing material. The root extract requires complex preparation involving baking, pounding and firing before it is ready for use. The seeds are edible. The timber is close grain and highly durable, this made it suitable for many purposes.

Scientific Name	Common Name/s	Use
<i>Hakea leucoptera</i>	Silver needlewood, needle hakea, pin bush, water tree, needlewood	The roots contain a drinkable watery sap, used as a substitute for pure water. The roots can be cut into lengths and stood on end to allow the liquid to drain out. The ends of the roots were also plugged with clay, and carried around while hunting or food gathering. The roots may also be blown at one end to expel the water. The summer flowers are white with eatable nectar
<i>Indigofera australis</i>	Austral indigo, native indigo	The leaves are crushed then added to water to kill or stun fish (Murray Cod) and eels. It usually takes a few days to effect the fish. The seed pod contains a chemical capable of producing hallucinations called hallucinogen
<i>Lomandra longifolia</i>	Spiny headed matrush	From the strap-shaped leaves women made baskets, nets and net-bags. After splitting each rush the women would then tie them into bundles to be soaked allowing the fibres to become suitable for weaving. Some usages for the baskets were fish and eel traps. The flowers are edible – tasty and starchy. Fruit are also edible – tough, ground into meal first

Scientific Name	Common Name/s	Use
<i>Macrozamia heteromera</i>	Commentary applies to this and following Macrozamia species found in the Southern Brigalow Belt	<p>Traditionally, the cycad plant is used for its seeds as a food source. However, the cycad seed contains cycasin which is an acutely toxic substance. Two to three seeds are sufficient to cause vomiting, diarrhoea and abdominal cramps (Beck <i>et al</i>). The part of the seed used is the softer kernel which lays inside a hard outer shell. Usage of the cycad is one of the more interesting of known Aboriginal plants, because of its toxicity and the skill required in selecting and preparing the seeds. Information of Aboriginal usage of cycad seeds comes from Northern Australia where it still forms a significant part of the diet among the Donydji people of northeast Arnhem Land. Three different methods of preparing the seeds for use are as follow. In northern Australia, the most common technique used is to gather dead fallen seeds from under the cycad plant. The fallen seeds are gathered after prolonged periods during which the seeds have often been subjected to fires and fungus, decreasing the levels of toxicity. The gathered seeds (called munbuwa) are still vigorously inspected and sorted using an acquired skill with smell and touch to determine the least toxic seeds for food preparation. The other technique involves leeching of the fresh nuts collected from the tree. These seeds will be highly toxic. Preparing the seeds for safe usage involves cracking the outer shell of the seed open to expose the softer kernel, which is then crushed and leached in running water for a week. After this it is ground into a paste, wrapped in paperbark and roasted in ashes for one hour. This method enables the cycad plant to be used during seasons when less dead seeds are available. A less known method involves rolling the removed kernels in hot sand mixed with charcoal, and then placed in a bag with charcoal. The contents of the bag are dried in the sun for several days, then leached in water. After 4-7 days the kernels are made into a long cake and roasted in a fire. Fragments of used macrozamia have been discovered in archaeological deposits in the Warrumbungles (Kawambrai Cave). How the seeds were prepared is unknown. However, one theory is that whole cones were gathered from the plants and cached in caves to dry the seeds prior to use.</p>
<i>Marsilea drummondii</i>	Nardoo, Southern cross	<p>Aboriginal women gathered Nardoo spores-cases once the water had dried up. The spore-cases were broken up on grindstones, and the spores were separated then ground between stones, removing the black husks the remaining yellow powder was mixed in with water to</p>

Scientific Name	Common Name/s	Use
		produce damper or porridge. Usually made when food was scarce or in hard times such as drought.
<i>Mentha satureioides</i>	Creeping mint, squeejit, and penneroi, native pennyroyal	Pennyroyal was placed on floors and in beds, it was very efficient in keeping insects, bugs and fleas away. In the south districts of NSW, pennyroyal was used by female's as a tea or decoction for irregular periods, with most satisfactory results
<i>Myoporum montanum</i>	Water bush, western boobialla, bush boobialla, boomeralla, native daphne, native myrtle	The plant is left in hot or boiling water for several minutes, the liquid is then used to scrub the head to treat general ailments. Leaves boiled for external use
<i>Opuntia stricta</i>	Common pest-pear, pest-pear, erect prickly pear, gayndah pear, common prickly pear, spiny prickly pear	Although an introduced species and considered a pest Aboriginal people interviewed in the oral history project as part of the cultural heritage assessment for the Brigalow Belt Bioregion often talked about prickly pear as a delicious refreshing fruit. Use of this fruit is especially common among Aboriginal drovers. A high cultural value among Aboriginal people
<i>Owenia acidula</i>	Native peach, gruie, sour plum, native nectarine, mooley apple, rancooran, warrongan, colane, moalie apple, gruie-colane, kangaroo apple, gooya	A wood decoction was used to bathe sore eyes. Emu apple apparently was used to treat malaria although there is no mention to which part of the tree was used. The fruit was also eaten.
<i>Persoonia</i> spp. (<i>curvifolia</i> , <i>sericea</i> and <i>cuspidifera</i>)	Geebung	The Geebung is a famous heathland plant. The word geebung is a traditional name thought to originate from New South Wales. Geebung fruit was an important food source. Mrs Maureen Sulter and her brother Mervyn Cain spoke of collecting Geebung berries at Burra Bee Dee Mission in Coonabarabran.

Scientific Name	Common Name/s	Use
<i>Phragmites australis</i>	Phragmites, cane grass	Underground shoots from the common reed are eaten. People from the lower Murray River made rectangular rafts by layering and bounding the long stems together; they were used for collecting mussels on inland lakes. The bamboo-like stems made excellent light spears, when the stem was cut into short lengths it was used to stick through the septum of the nose as an ornament or it could be threaded onto fibre or animal fur and worn around the neck for both women and men. Baskets and bags were made from the leaves
<i>Pimelea linifolia</i>	Ganny's bonnet, queen-of-the-bush, flax-leaf rice-flower, white riceflower, native candy-tuft, buttons, slender rice flower	String was made from riceflower bark and was known as 'Bushman's Bootlace'. The bark was first striped off the shrub, dried, then placed in a stream for about a week then dried once more. Next, the bark was softened by chewing or beating with sticks and stones then rolled on the thigh and spun to a fine strong thread. The string could be used for numerous purposes such as net making
<i>Pittosporum phylliraeoides</i>	Western pittosporum, berrigan, locketbush, native willow, poison-berry tree, inland pittosporum, cheesewood, meeimeei, cumby cumby, cattle bush, weeping pittosporum, wild apricot, narrow-leaved pittosporum, dessine	During autumn a gum is collected from the branches and eaten, the gum contains high amounts of carbohydrates, but does not offer much in the way of taste. The seeds are pound into flour for food usage or ground to form an oily paste, which is then rubbed on sore areas of the body. An infusion of leaf, fruit and wood was prepared, the brew is taken internally or applied externally for a variety of illnesses including internal pains, sprained limbs and skin irritations such as eczema. In some parts of New South Wales the leaves are warmed than placed on a mothers breast to induce the first flow of milk following childbirth.
<i>Portulaca oleracea</i>	Munyeroo, Purslane, pigweed	Common pigweed was eaten by Aboriginals, early Australian explorers and settlers, both raw and as a cooked vegetable. It contains high amounts of protein, water, dietary fibre and trace elements. Pigweed actually contains 18.5 per cent protein compared with 11.5 per cent for wholemeal bread and only 6.9 per cent for brown rice. Although pigweed was quite a good source of minerals European settlers believed it to cure scurvy, recent tests by the department of Defence Support showed only traces of vitamin C. After collecting the seeds in a coolamon

Scientific Name	Common Name/s	Use
		they were ground in between stones, adding water the mixture was ready to be baked in hot ashes to produce damper or cakes, similar tasting to linseed. Seeds could be stored for long periods of time making them a stable and reliable source of food especially in times of drought. In some cases the whole plant, stem and leaves were ground with stones to create a thick green edible paste. The mush was eaten immediately. This food source could also be rolled into balls dried and then recreated latter by soaking in water
<i>Santalum acuminatum</i>	Sweet quandong, native quandong, desert quandong, quandong	Quandongs were a useful source of food. Due to the high content of water contained in the fruit quandongs were often gathered during droughts. Dehydrated fruit may also have been pounded in to a paste. The kernel was extracted when it could be heard knocking from inside the stone. It may be eaten raw or pounded so the oil can be removed and used as a cosmetic to smooth the skin of face or body. Aborigines were able to distinguish trees that may have 'good' kernels and which may be toxic. The stones were made up into necklaces and ornaments. Aboriginal people interviewed in the oral history project as part of the cultural heritage assessment for the Brigalow Belt South Bioregion often talked about quandongs. Quandongs have high cultural value among Aboriginal people
<i>Sarcostemma australe</i>	Caustic bush, milk bush, tableland caustic bush, caustic plant, ley bush, snake plant, milk vine, pencil caustic, snake vine	A rubbing medicine. <i>Kiji kiji</i> is used on scabies and irritating sores by breaking the stem and dabbing the white sap on to the affected area. It is best to use the sap after rain because the flow is much stronger. The whole vine as well as the sap were also warmed and rubbed on women's breasts to induce lactation
<i>Sonchus oleraceus</i>	Sowthistle, annual sowthistle, thalaak, common sowthistle	This species is eaten raw in western Victoria to ease pain and induce sleep. Leaves roots and stems of the common milk thistle were eaten. European settlers cooked the shoots as a vegetable. Villagers in Asia and Africa also eat this species. E. Stephens, a settler near Adelaide, even witnessed a thistle feast: "the Aborigines" saw about a quarter of an acre of luxuriant sow thistle on our land. Some of them asked if they might have them. I obtained the requisite permission, and told them that they could take the lot. In a moment they had climbed the fence, and this little plot was one mass of seething men, women and children. Ten minutes

Scientific Name	Common Name/s	Use
		later the ground was bare of thistles, and the tribe passed on gratefully devouring the juicy weed.”
<i>Styphelia triflora</i>	Five corners	The edible berry found growing on this species is quite favoured among Aboriginal people within the Brigalow Belt South. Mrs Maureen Sulter (Coonabarabran) as a child remembers collecting five corners in little tins or jars at Burra Bee Dee. Dan Trindall (Narrabri) mentioned his uncle Barry Williams who worked in the Pilliga scrub as a dingo trapper teaching him about the five corners and many other bush fruits. Five corners is a plant food commonly known to the Toomelah/Boggabilla community.
<i>Themeda</i> spp. (<i>australis</i> and <i>avenacea</i>)	Kangaroo grass	The seeds are ground and baked. A closely related species, <i>Themeda avenacea</i> know as Native oatgrass is similar but larger & has larger needs. The seeds of this species may also have been used. It grows in depressions & floodways and good soils in drier regions of the Brigalow Belt South Bioregion and the north west slopes & plains of NSW
<i>Thysanotus tuberosus</i>	Fringed violet, violet lily, 1bulb, and 2bulb (depending on amount of bulbs produced), goomei or goomyeye.	Under the ground the roots swell into small sugary tubers that are dug up with digging sticks, the roots and base of the stem can both be eaten. A hard shell surrounds the roots, which splits open when the tuber is cooked in hot ashes
<i>Typha orientalis</i>	Broad-leaved cumbungi, cat's-tail, reed-mace, wonga, miranda	The rhizomes were collected by Aborigines and ground to make a type of flour from which cakes were produced, the glutinous rhizome also provided starch, sugar, and a considerable amount of fibre seasonally to the people of Victoria and New South Wales. The strap-like leaves have been used in the production of mats and baskets. In the Marshlands of south western Australia and the Murray Darling system of New South Wales the very new white to green shoots of these rushes are gathered during spring and early summer and either eaten raw or cooked. The fluffy seed heads were once collected along the Murray River and sold as stuffing for pillows. According to the Explorer Thomas Mitchell, bulrushes were the principle food of Aborigines of the Lachlan River. He observed the Aborigines gathering large bundles and carrying them in net bags on their heads. String was made from bulrushes by steaming

Scientific Name	Common Name/s	Use
		the stems in an earth oven. After steaming, the stems they were chewed removing starch and the remaining fibre was used to make the string.
<i>Urtica incisa</i>	Tall nettle, scrub nettle, stinging nettle	It is known in some areas that stinging nettle was used for rheumatism, the affected area is beaten with a bunch of leaves to cause a nettle rash. Another usage was for sprains, an infusion of leaves was created to bathe the sprain in, and boiled leaves were also used as a poultice
<i>Xanthorrhoea australis</i>	Grass trees	Grass trees were once a multiple source of food. Flowers contain a considerable amount of nectar and were soaked in water to make a sweet drink. The soft basal parts of the leaves, as well as the stem were eaten. Nutty tasting starch was gouged from the top of the trunk. The tall straight stems of the flower spikes, which were up to 3 m long, made excellent light spear shafts. They were attached to the lower end of spears to extend their length and, therefore, range. The section of the spear closest to the tip was of harder wood that could withstand impact. To haft the spears, the gum from the grass tree was used. The gum when slightly heated would form a liquid and then reharden when cooled, fibrous material such as wood shavings were added during the process. This method helped to shape the resin making it easier to attach stone flakes to spears, to make handles for numerous stone implements, and to fasten stone axe-heads to wooden handles. At Bunbury in southwest Australia, soaking the flower heads or cones of grass trees made a drink called mangaitj. The mixture was allowed to ferment for several days in water in a bark trough. It was reported to make people excited and voluble. The tree age can be determined by the height of the trunk, early photos show trees twice the height of a human. It is quite rare to find specimens of such height today. Grass trees are now a protected species. To make a fire, the dry stalk from the flowering part of the grass tree (<i>Xanthorrhoea australis</i>) was used serving as a base in which a stem of Austral Mulberry (<i>Hedycarya angustifolia</i>) was spun or drilled rapidly, both of these species are found within the boundaries of the Brigalow Belt South.

Appendix B Threats and management actions

Table 19 to **Table 22** outline the potential threats and respective recovery actions which apply to each threatened species either known or with the potential to occur in the study area

The following key applies to each table:

Likelihood of occurrence:

P = Potential

K = Known

Threats and recovery actions:

1 = threat or recovery directly stated in reference source

2 = threat or recovery action implied by the recommendation by listing of threat or detailing a management strategy (e.g. feral cats listed as a threat but “control feral cats” not explicitly listed as a management strategy)

Table 19: Threats to threatened fauna species known or with the potential to occur in the study area

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Predation/competition by feral animals						Loss of hollow-bearing trees	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores					Competition from noisy miners	Removal of fallen timber/dead trees	Competition from feral bees	Info sources		
					Feral predators	Foxes	Cats	Wild dogs	Rats/Mice	Unspecified						Unspecified	Pigs	Rabbits	Goats	Horses						
<i>Aepyprymnus rufescens</i>	Rufous Bettong	V	~	P	1	1	1	1				2	1	2	1			1					1			(OEH, 2015); (Kavanagh & Stanton, 2005)
<i>Anseranas semipalmata</i>	Magpie Goose	V	Mar	P	1	1				1			1	1	1											(OEH, 2015); (DotE, 2017)
<i>Anthochaera phrygia</i>	Regent Honeyeater	CE	E, M	P	1	2	1					1	1		1					1		1				(ACT Government, 1999b), (OEH, 2015), (DECCW, 1999)
<i>Apus pacificus</i>	Fork-tailed Swift	-	M, Mar	K	1		1																			(DotE, 2017)
<i>Ardea alba</i>	Great Egret, White Egret	~	M, Mar	K								1		1												(DotE, 2017)
<i>Ardea ibis</i>	Cattle Egret	~	M, Mar	K	1		1																			(DotE, 2017)
<i>Ardeotis australis</i>	Australian Bustard	E1	~	P	1	1	1					2			1		1		1							(OEH, 2015)
<i>Botaurus poiciloptilus</i>	Australasian Bittern	E1	E	P	1	1	1	1				1			1	1										(OEH, 2015); (DotE, 2017)
<i>Burhinus grallarius</i>	Bush Stone-curlew	E1	~	P	1	1	1	1				1		1	1		1						1			(OEH, 2015); (DEC, 2006b)
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper		M, Mar	P										1												
<i>Calyptorhynchus lathamii</i>	Glossy Black-Cockatoo	V	~	K							1	1			1	1										(OEH, 2015)
<i>Cercartetus nanus</i>	Eastern Pygmy-possum	V	~	K	1	1	1	1				1			1								1			(OEH, 2015)
<i>Chalinolobus dwyeri</i>	Large-eared Pied Bat	V	V	P	1	1						1			1											(OEH, 2015); (DotE, 2017)
<i>Chalinolobus picatus</i>	Little Pied Bat	V	~	K	1		1																			(OEH, 2015)

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Predation/competition by feral animals						Loss of hollow-bearing trees	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores					Competition from noisy miners	Removal of fallen timber/dead trees	Competition from feral bees	Info sources	
					Feral predators	Foxes	Cats	Wild dogs	Rats/Mice	Unspecified						Unspecified	Pigs	Rabbits	Goats	Horses					
<i>Chthonicola sagittata</i>	Speckled Warbler	V	~	K	1	1	1	1	1			1		1	1			1				1			(OEH, 2015)
<i>Circus assimilis</i>	Spotted Harrier	V	~	K										1											(Attwood et al., 2009)
<i>Daphoenositta chrysoptera</i>	Varied Sittella	V	~	K									2								1	1			(OEH, 2015)
<i>Dasyurus maculatus</i>	Spotted-tailed Quoll	V	E	P	1	1	1	1				1		1	1							1			(DECCW, 2010); (OEH, 2015); (TSSC, 2004)
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork	E1	~	K										2	2										(OEH, 2015)
<i>Falco hypoleucos</i>	Grey Falcon	E1	~	P											1										(OEH, 2015)
<i>Falco subniger</i>	Black Falcon	V	~	K											1										(NSW Scientific Committee, 2013)
<i>Gallinago hardwickii</i>	Latham's Snipe, Japanese Snipe	~	M, Mar	P	1	1								1	1										(DotE, 2017)
<i>Glossopsitta pusilla</i>	Little Lorikeet	V	~	K							1	2													(OEH, 2015)
<i>Grantiella picta</i>	Painted Honeyeater	V	~	K											1			1							(DSE, 2003a); (OEH, 2015)
<i>Grus rubicunda</i>	Brolga	V	~	P	1	1						1			1										(DSE, 2003b)
<i>Haliaeetus leucogaster</i>	White-bellied Sea-Eagle	~	M, Mar	K																					
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard	V	~	P											1										(OEH, 2015)
<i>Hieraaetus morphnoides</i>	Little Eagle	V	~	K											1							2			(OEH, 2015)
<i>Hirundapus caudacutus</i>	White-throated Needle-tail	-	M, Mar	K																					
<i>Hoplocephalus bitorquatus</i>	Pale-headed Snake	V	~	K								1			2							1			(OEH, 2015)

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Predation/competition by feral animals						Loss of hollow-bearing trees	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores					Competition from noisy miners	Removal of fallen timber/dead trees	Competition from feral bees	Info sources	
					Feral predators	Foxes	Cats	Wild dogs	Rats/Mice	Unspecified						Unspecified	Pigs	Rabbits	Goats	Horses					
<i>Lathamus discolor</i>	Swift Parrot	E1	E, Mar	P	1		1				1	1			1						1				(DotE, 2017);
<i>Lophoictinia isura</i>	Square-tailed Kite	V	~	K								1			1										(OEH, 2015)
<i>Macropus dorsalis</i>	Black-striped Wallaby	E1	~	K	1	1	1					1		1	1			1	1						(OEH, 2015)
<i>Melanodryas cucullata cucullata</i>	Hooded Robin (south-eastern form)	V	~	K	1	1	1	1				1		1	1						1	1			(ACT Government, 1999a); (NSW Scientific Committee, 2008a); (OEH, 2015)
<i>Melithreptus gularis gularis</i>	Black-chinned Honeyeater (eastern subspecies)	V	~	K											1						1				(OEH, 2015)
<i>Merops ornatus</i>	Rainbow Bee-eater	~	M, Mar	K	1	1		1																	(DotE, 2017)
<i>Miniopterus schreibersii oceanensis</i>	Eastern Bentwing-bat	V	~	K	1	1	1					1		1											(OEH, 2015)
<i>Myiagra cyanoleuca</i>	Satin Flycatcher	~	M, Mar	K																					
<i>Neophema pulchella</i>	Turquoise Parrot	V	~	K	1	1	1				1			1	1		2		2						(OEH, 2015)
<i>Ninox connivens</i>	Barking Owl	V	~	K	1	1	1				1	1	1	1	1							1			(OEH, 2015); (NPWS, 2003)
<i>Nyctophilus corbeni</i> (syn. <i>Nyctophilus timoriensis</i> (South-eastern form))	South-eastern Long eared Bat / Corben's Long-eared Bat	V	V	K						1	1	1		1						1					(DotE, 2017)
<i>Oxyura australis</i>	Blue-billed Duck	V	~	P	1	2						1			1										(OEH, 2015)

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Predation/competition by feral animals						Loss of hollow- bearing trees	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores					Competition from noisy miners	Removal of fallen timber/dead trees	Competition from feral bees	Info sources		
					Feral predators	Foxes	Cats	Wild dogs	Rats/Mice	Unspecified						Unspecified	Pigs	Rabbits	Goats	Horses						
<i>Pachycephala inornata</i>	Gilbert's Whistler	V	~	P								1			1											(OEH, 2015)
<i>Petaurus norfolcensis</i>	Squirrel Glider	V	~	K	1	1	1	1			1	1	2	1	1	1				2						(DSE, 2004); (NSW Scientific Committee, 2008b); (OEH, 2015); (Woinarski, Burbidge, & Harrison, 2014)
<i>Petroica boodang</i>	Scarlet Robin	V	~	P			1		1			2	1	1	1							1				(OEH, 2015)
<i>Phascolarctos cinereus</i>	Koala	V	V	K				1				1		1	1											(DECC, 2008); (OEH, 2015); (Woinarski et al., 2014)
<i>Polytelis swainsonii</i>	Superb Parrot	V	V	P	1	1	1				1	1			1								1			(ACT Government, 1999c); (OEH, 2015); (Baker-Gabb, 2011)
<i>Pomatostomus temporalis temporalis</i>	Grey-crowned Babbler (eastern subspecies)	V	~	K	1	1	1							1	1						1	1				(DSE, 2001); (OEH, 2015)
<i>Pseudomys pilligaensis</i>	Pilliga Mouse	V	V	K	1	1	1		1			1					1									(DotE, 2017); (OEH, 2015)
<i>Rostratula australis (syn. Rostratula benghalensis australis)</i>	Australian Painted Snipe	E1	E, Mar	P	1	1	1	1				1		1	1											(DotE, 2017); (OEH, 2015)
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail-bat	V	~	K							1															(OEH, 2015)
<i>Scoteanax rueppellii</i>	Greater Broad-nosed Bat	V	~	K							1	1														(OEH, 2015); (Woinarski et al., 2014)
<i>Sminthopsis macroura</i>	Stripe-faced Dunnart	V	~	P	1	1	1					1			1		2	2	2			1				(OEH, 2015)

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Predation/competition by feral animals						Loss of hollow- bearing trees	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores					Competition from noisy miners	Removal of fallen timber/dead trees	Competition from feral bees	Info sources
					Feral predators	Foxes	Cats	Wild dogs	Rats/Mice	Unspecified						Unspecified	Pigs	Rabbits	Goats	Horses				
<i>Stagonopleura guttata</i>	Diamond Firetail	V	~	K							1		1	1			1				1			(OEH, 2015)
<i>Stictonetta naevosa</i>	Freckled Duck	V	~	P						2	2			1		2		2						(OEH, 2015)
<i>Tyto novaehollandiae</i>	Masked Owl	V	~	K	1	1					1	1	1		1						1			(DEC, 2006b);(DSE, 2003c); (OEH, 2015)
<i>Vespadelus troughtoni</i>	Eastern Cave Bat	V	~	K	1	1	1				1			1				2						(OEH, 2015)
TOTAL COUNT:					31	27	25	11	3	3	11	36	7	20	42	3	6	9	7	1	6	16	1	

Table 20: Management actions that benefit threatened fauna species known or with the potential to occur in the study area

Scientific name	Common name	BC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/replacement woody	Info sources	
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses					
<i>Aepyprymnus rufescens</i>	Rufous Bettong	V	~	P	1	1	2			1		1	1		1								1	(OEH, 2015)	
<i>Anseranas semipalmata</i>	Magpie Goose	V	Mar	P	2				1	1		1	1												(OEH, 2015)
<i>Anthochaera phrygia</i>	Regent Honeyeater	CE	E, M	P	1	1				1			1				1					1	2	(OEH, 2015); (QLD EPA, 2008)	
<i>Apus pacificus</i>	Fork-tailed Swift	-	M, Mar	K		2																			
<i>Ardea alba</i>	Great Egret, White Egret	~	M, Mar	K						2		2													
<i>Ardea ibis</i>	Cattle Egret	~	M, Mar	K		2																			
<i>Ardeotis australis</i>	Australian Bustard	E1	~	P	1	1				1			1	1		1		1							(OEH, 2015)
<i>Botaurus poiciloptilus</i>	Australasian Bittern	E1	E	P	1	1	2			1			1	1	2										(OEH, 2015)
<i>Burhinus grallarius</i>	Bush Stone-curlew	E1	~	P	1	1	1			2		1	1	1								1	1		(OEH, 2015); (DEC, 2006a)
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper		M, Mar	P								2													(DotE, 2017)
<i>Calyptorhynchus lathami</i>	Glossy Black-Cockatoo	V	~	K					1	1			1												(OEH, 2015)
<i>Cercartetus nanus</i>	Eastern Pygmy-possum	V	~	K	1	1	1			1			1										1		(OEH, 2015)
<i>Chalinolobus dwyeri</i>	Large-eared Pied Bat	V	V	P	1					1			1												(OEH, 2015)
<i>Chalinolobus picatus</i>	Little Pied Bat	V	~	K		1																			(OEH, 2015)
<i>Chthonicola sagittata</i>	Speckled Warbler	V	~	K	1	1				2		2	1	1			2						1		(OEH, 2015)
<i>Circus assimilis</i>	Spotted Harrier	V	~	K									1												(OEH, 2015)
<i>Daphoenositta chrysoptera</i>	Varied Sittella	V	~	K								1	1										1		(OEH, 2015)
<i>Dasyurus maculatus</i>	Spotted-tailed Quoll	V	E	P	1	1	2			1		2	2												(ACT Government, 2005), (OEH, 2015)

Scientific name	Common name	BC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/ placement woody	Info sources		
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses						
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork	E1	~	K								1	1													(OEH, 2015)
<i>Falco hypoleucos</i>	Grey Falcon	E1	~	P									1													(OEH, 2015)
<i>Falco subniger</i>	Black Falcon	V	~	K									2													
<i>Gallinago hardwickii</i>	Latham's Snipe, Japanese Snipe	~	M, Mar	P	2						2		2													
<i>Glossopsitta pusilla</i>	Little Lorikeet	V	~	K						1																(OEH, 2015)
<i>Grantiella picta</i>	Painted Honeyeater	V	~	K									1				2									(OEH, 2015)
<i>Grus rubicunda</i>	Brolga	V	~	P	1						2		1													(DSE, 2003b); (OEH, 2015)
<i>Haliaeetus leucogaster</i>	White-bellied Sea-Eagle	~	M, Mar	K																						
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard	V	~	P									1											1		(OEH, 2015)
<i>Hieraaetus morphnoides</i>	Little Eagle	V	~	K																						
<i>Hirundapus caudacutus</i>	White-throated Needle-tail	-	M, Mar	K																						
<i>Hoplocephalus bitorquatus</i>	Pale-headed Snake	V	~	K						1			1												2	
<i>Lathamus discolor</i>	Swift Parrot	E1	E, Mar	P		2					2		1													(DotE, 2017); (Swift Parrot Recovery Team, 2011)
<i>Lophoictinia isura</i>	Square-tailed Kite	V	~	K						1			2													
<i>Macropus dorsalis</i>	Black-striped Wallaby	E1	~	K	1	1					1	1	1				1	1								
<i>Melanodryas cucullata cucullata</i>	Hooded Robin (south-eastern form)	V	~	K	2	2	2				2	2	1											1		(OEH, 2015)
<i>Melithreptus gularis gularis</i>	Black-chinned Honeyeater (eastern subspecies)	V	~	K									2													(OEH, 2015)
<i>Merops ornatus</i>	Rainbow Bee-eater	~	M, Mar	K	2		2																			(DotE, 2017)

Scientific name	Common name	BC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/ placement	woody	Info sources	
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses						
<i>Miniopterus schreibersii oceanensis</i>	Eastern Bentwing-bat	V	~	K	1	1				1		1														(OEH, 2015)
<i>Myiagra cyanoleuca</i>	Satin Flycatcher	~	M, Mar	K																						
<i>Neophema pulchella</i>	Turquoise Parrot	V	~	K	1	1						1	1				1		1							(OEH, 2015)
<i>Ninox connivens</i>	Barking Owl	V	~	K	2	2				1	2	2	1										1			(OEH, 2015)
<i>Nyctophilus corbeni</i> (syn. <i>Nyctophilus timoriensis</i> (South-eastern form))	South-eastern Long eared Bat / Corben's Long-eared Bat	V	V	K					1	1			2						2							(DotE, 2017)
<i>Oxyura australis</i>	Blue-billed Duck	V	~	P	1					1			1													(OEH, 2015)
<i>Pachycephala inornata</i>	Gilbert's Whistler	V	~	P						1			1													(OEH, 2015)
<i>Petaurus norfolcensis</i>	Squirrel Glider	V	~	K	2	2	2			1	1	2	1										1			(OEH, 2015); (Woinarski et al., 2014)
<i>Petroica boodang</i>	Scarlet Robin	V	~	P		1		1		1	2	2	1											1		(OEH, 2015)
<i>Phascolarctos cinereus</i>	Koala	V	V	K			1			1		2	2													(DECC, 2008); (OEH, 2015); (Woinarski et al., 2014)
<i>Polytelis swainsonii</i>	Superb Parrot	V	V	P	2	2				1			1									1				(DotE, 2017); (OEH, 2015)
<i>Pomatostomus temporalis temporalis</i>	Grey-crowned Babbler (eastern subspecies)	V	~	K	2	1						2	1											1		(DSE, 2001); (OEH, 2015)
<i>Pseudomys pilligaensis</i>	Pilliga Mouse	V	V	K	1	1		1		1							2									(DotE, 2017); (OEH, 2015)
<i>Rostratula australis</i> (syn. <i>Rostratula benghalensis australis</i>)	Australian Painted Snipe	E1	E, Mar	P	1	1	1			1		2	1													(DotE, 2017); (OEH, 2015)
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail-bat	V	~	K																						
<i>Scoteanax rueppellii</i>	Greater Broad-nosed Bat	V	~	K						2																(OEH, 2015)
<i>Sminthopsis macroura</i>	Stripe-faced Dunnart	V	~	P	1	1				1			1	1			1	1	1					1		(OEH, 2015)
<i>Stagonopleura guttata</i>	Diamond Firetail	V	~	K						2		1	1					2						1		(OEH, 2015)

Scientific name	Common name	BC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/placement	woody	Info sources	
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses						
<i>Stictonetta naevosa</i>	Freckled Duck	V	~	P					1	1			1			1		1								(OEH, 2015)
<i>Tyto novaehollandiae</i>	Masked Owl	V	~	K	2					2	2		2										2			
<i>Vespadelus troughtoni</i>	Eastern Cave Bat	V	~	K	1	1				1			2					1								(OEH, 2015)
TOTAL COUNT:					27	25	10	2	3	1	36	5	20	42	5	2	6	6	7	1	1	2	15			

Table 21: Threats to threatened flora species known or with the potential to occur in the study area

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Inappropriate fire regimes	Forest structural changes	Weed invasion	Grazing pressure (general)	Feral herbivores				Info sources
									Pigs	Rabbits	Goats	Horses	
<i>Bertya opponens</i>	Coolabah Bertya	V	V	K	1		1				1		(DotE, 2017); (OEH, 2015)
<i>Cyperus conicus</i>	A sedge	E1	~	P				1		1			(OEH, 2015)
<i>Desmodium campylocaulon</i>	Creeping Tick-Trefoil	E1	~	P				1					(OEH, 2015)
<i>Dichanthium setosum</i>	Bluegrass	V	V	P	1		1	1		2			(DotE, 2017); (OEH, 2015)
<i>Digitaria porrecta</i>	Finger Panic Grass	E1		P	1		1	1					(OEH, 2015)
<i>Diuris tricolor</i>	Painted Diuris	V	~	K			1			1	1		(OEH, 2015)
<i>Homopholis belsonii</i>	Belson's Panic	E1	V	P		1	1	1					(DotE, 2017); (OEH, 2015)
<i>Lepidium aschersonii</i>	Spiny Peppergrass	V	V	K			1	1	1	1			(DotE, 2017); (OEH, 2015)
<i>Lepidium monoplocoides</i>	Winged Peppergrass	E1	E	K			1	1	1	1			(DotE, 2017); (OEH, 2015)
<i>Monotaxis macrophylla</i>	Large-leafed Monotaxis	E1	~	P	1								(OEH, 2015)
<i>Myriophyllum implicatum</i>		CE	~	K			1		1				(OEH, 2015)
<i>Polygala linariifolia</i>	Native Milkwort	E1	~	K	1		1	1		1	1		(OEH, 2015)
<i>Pomaderris queenslandica</i>	Scant Pomaderris	E1	~	K	1		1						(OEH, 2015)
<i>Pterostylis cobarensis</i>	Greenhood Orchid	V	~	K			1	1	1	1	1		(OEH, 2015)
<i>Rulingia procumbens</i>		V	V	K	1	1							(OEH, 2015)
<i>Tylophora linearis</i>	-	V	E	K	1		1	1	1		1		(NSW Scientific Committee, 2008c); (OEH, 2015); (TSC, 2008)
TOTAL COUNT:					8	2	12	10	5	7	5	0	

Table 22: Management actions that benefit threatened flora species known or with the potential to occur in the study area

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Fire management	Ecological thinning	Weed control	Grazing management/ stock exclusion	Fenced refugia	Feral herbivore control				Info sources
										Pigs	Rabbits	Goats	Horses	
<i>Bertya opposens</i>	Coolabah Bertya	V	V	K	1		1					1		(DotE, 2017); (OEH, 2015)
<i>Cyperus conicus</i>	A sedge	E1	~	P				2				2		(OEH, 2015)
<i>Desmodium campylocaulon</i>	Creeping Tick-Trefoil	E1	~	P				1	1					(OEH, 2015)
<i>Dichanthium setosum</i>	Bluegrass	V	V	P	1		1	1				1		(DotE, 2017); (OEH, 2015)
<i>Digitaria porrecta</i>	Finger Panic Grass	E1		P	1		2	1						(OEH, 2015)
<i>Diuris tricolor</i>	Painted Diuris	V	~	K			2					2	2	(OEH, 2015)
<i>Homopholis belsonii</i>	Belson's Panic	E1	V	P			1	1						(DotE, 2017); (OEH, 2015)
<i>Lepidium aschersonii</i>	Spiny Peppergrass	V	V	K			1	1			1	1		(Carter, 2010); (DotE, 2017); (OEH, 2015)
<i>Lepidium monoplocoides</i>	Winged Peppergrass	E1	E	K			1	1			2	1		(DotE, 2017); (Mavromihalis, 2010); (OEH, 2015)
<i>Monotaxis macrophylla</i>	Large-leafed Monotaxis	E1	~	P	1									(OEH, 2015)
<i>Myriophyllum implicatum</i>		CE	~	K			1				1			(OEH, 2015)
<i>Polygala linariifolia</i>	Native Milkwort	E1	~	K	1		1	1				1	1	(OEH, 2015)
<i>Pomaderris queenslandica</i>	Scant Pomaderris	E1	~	K	1		1							(OEH, 2015)
<i>Pterostylis cobarensis</i>	Greenhood Orchid	V	~	K			1	1	1		2	2	2	(OEH, 2015)
<i>Rulingia procumbens</i>		V	V	K	1	1								(OEH, 2015)
<i>Tylophora linearis</i>	-	V	E	K	1		1	1			2		2	(NSW Scientific Committee, 2008c); (OEH, 2015); (TSC, 2008)

Scientific name	Common name	BC Act Status	EPBC Act Status	Likelihood of occurrence	Fire management	Ecological thinning	Weed control	Grazing management/ stock exclusion	Fenced refugia	Feral herbivore control				Info sources
										Pigs	Rabbits	Goats	Horses	
TOTAL COUNT					8	1	12	10	2	5	7	5	0	

Appendix C Koala Research Proposal

CONSERVING KOALAS ACROSS THE PILLIGA SCRUB

RESEARCH PROPOSAL

Principal Investigator: Dr. Stephen Phillips

Biolink Pty Ltd.

PO Box 3196 Uki NSW 2484

Tel: 02 6679 5523

(Email: steve@biolink.com.au)

Background

In recent years there has been a dramatic decline in koala numbers inhabiting the Pilliga Scrub in central western NSW. Recently available data arising from intensive field surveys by several independent researchers over 2013 – 2014 collectively implies a reduction of as much as 95% in the habitat occupancy rate over the last three koala generations (i.e. 18 – 20 years), a finding that arguably qualifies the remaining population(s) as Critically Endangered by International, National and State-focused conservation criteria. The reasons for the dramatic decline remain to be determined but likely include the effects of drought compounded by the cumulative impacts of high intensity/frequency wildfire, aspects of both being arguably exacerbated by anthropogenic climate change. The distribution of remaining koala population cells, aside from generally (but not always) being associated with proximity to water, remains difficult to model and/or predict with certainty.

Whatever the reasons for the decline of koalas across the Pilliga Scrub, there is considerable interest in halting the decline and assisting recovery by way of directing management effort into areas supporting the remaining population cells. However, in order to focus management effort efficiently and expeditiously, there is an over-riding need to know exactly where the remaining populations are located, along with knowledge about how many koalas comprise the population.

Regularised Grid-based Spot Assessment Technique (R**G**b-SAT) sampling is being regularly applied throughout eastern Australia in areas where koalas are considered to occur, the technique repeatedly demonstrating a capacity to provide robust data and information about koala population size, distribution and habitat use both at the macro-landscape and local population scale. The R**G**-bSAT approach offers a number of advantages over more conventional survey techniques by adopting a completely unbiased yet systematic approach to survey design while also being able to operate at varying scales depending on what the specific research objective is. By example, simple occupancy data (i.e. presence of koalas within a predetermined *Extent of Occurrence*) can be simply obtained by using a coarse sampling regime of regularly spaced field sites located at say 2 – 4 km intervals or alternatively, finer-scale output that delineates the precise boundaries of resident meta-population cells (i.e. areas occupied by and/or supporting resident koala populations) can be obtained by modelling koala activity data obtained at 500 m and 350 m sampling intervals in areas known to be occupied by the species (Figure 1).

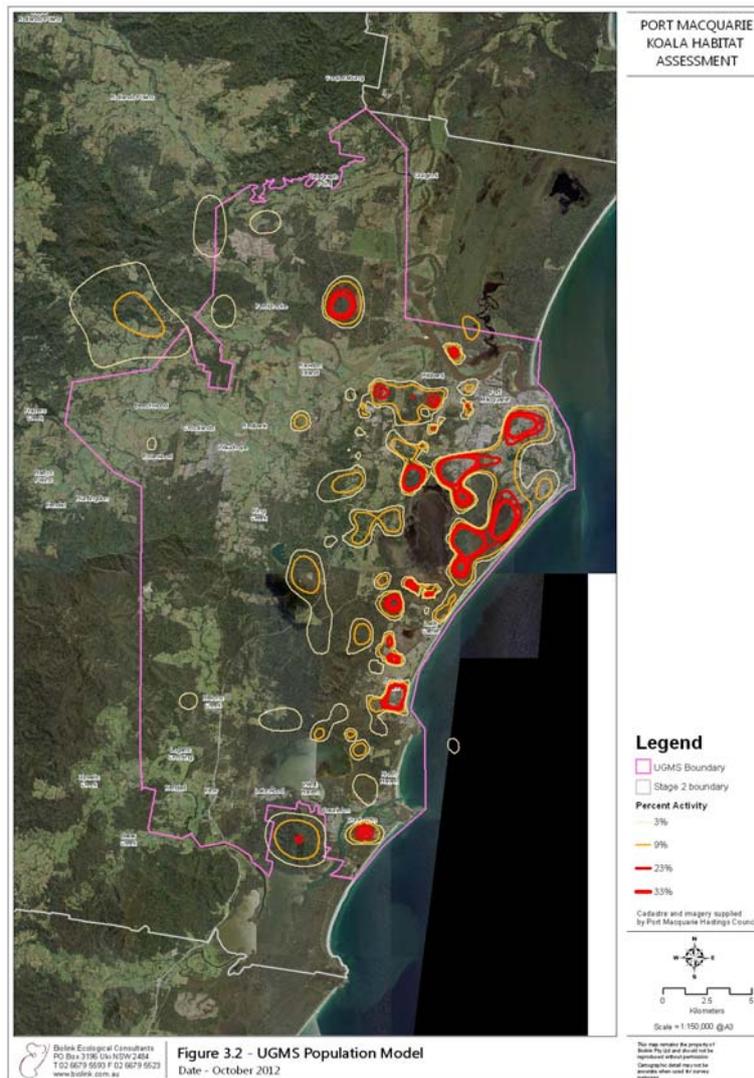


Figure 1. Koala meta-population model for a 74,000 ha coastal portion of the Port Macquarie Hastings Local Government area on the mid-north coast of NSW. The model was based on interpolation of koala activity data collected using the RG-bSAT approach with sampling intervals of 250 m – 1000 m. Across the LGA, habitat occupancy by resident populations based on sampling at 4000 m intervals was estimated at ~24% of available habitat.

Research Proposal

This proposal envisages establishing a 500 m survey grid across the entire ~ 600,000 ha of Pilliga Scrub, the intent to establish a permanently fixed grid that can be surveyed at varying scales, initially at 8 km sampling intersections in order to provide an unbiased occupancy estimate. At this scale of sampling approximately 120 primary field sites would be involved.

Working off the same grid but at a finer resolution of sampling (i.e. 250 m - 500 m intervals) in areas where relic populations have been detected or are otherwise known to occur, we would prepare koala meta-population models that delineate the precise areas being utilized by resident populations with a view to enabling a focusing of management/recovery effort on such issues as weed control, fire suppression and other threatening processes. The models will be accompanied by robust koala density

estimates with the actual number of animals comprising the relic population cell precisely identified with 95% confidence.

In order to demonstrate the outcome and potential of this latter approach this proposal envisages focusing on at least two localities where koalas were detected during the 2013 –2014 survey program. Other localities may also be considered. All grid points once sampled have utility for longer-term monitoring biodiversity and koala population monitoring purposes.

Additional funding would be sought to capture additional population cells following completion of this project and/or government/community/industry staff could be trained in the technique with a view to developing a program of ongoing assessment and monitoring.

Project Costs

Working on the basis of discounted professional rates, estimated project costs for the project are in the vicinity of A\$65 – A\$70K (Excl GST) as follows:

Task 1: Provision of Pilliga-wide unbiased occupancy estimate

(Field crew: n = 2)

Travel: 2,700kms at A\$0.75 km ⁻¹	2,025
Accommodation (allowance): 22 person days @ A\$125.00 day ⁻¹	2,750
Salaries & on-costs: 22 person days at A\$500.00 day ⁻¹	11,000
Data analysis, mapping & reporting: 5 days @ A\$500 day ⁻¹	2,500

Total project cost (exc GST)..... 18,275

Note: some funds (approx A\$10K) are already available to assist completion of this task (i.e. unbiased occupancy estimate); this proposal is thus only seeking funds to the extent of A\$8,275.

Task 2: Koala meta-population models x 2

(Field crew: n = 3)

For each of the two koala meta-population models envisaged by this component of the project we estimate costs on the vicinity of A\$25K (exc GST) in both instances, these being the funds required to transport, accommodate and remunerate a field survey team of three people for a minimum of 10 – 12 days, a breakdown of which is as follows:

Travel: 2,700 kms at A\$0.75 km ⁻¹	2,025
Accommodation (allowance): 32 person days @ A\$125.00 day ⁻¹	4,000
Salaries and on-costs: 32 person days @ A\$500 day ⁻¹	16,000
Data analysis, GIS modeling and reporting: 7 days at \$A500.00 day ⁻¹ ...	3,500

Total project cost for each model 25,525

Project Management

Projects would be managed as consultancies, the results expected to be in a format suitable for use by agencies and/or industry in terms of directing management

responses, while also being suitable for publication in a peer-reviewed scientific journal.

About the Principal Investigator

Dr. Stephen Phillips is an internationally acknowledged authority on koalas and has over 40 years of demonstrable experience in management of the species. In 1998 and while employed as Principal Biologist with the Australian Koala Foundation his work on processes of habitat assessment and koala population management was recognised by the Smithsonian Institute. In addition to presentations at seminars and conferences he has written book chapters on koalas and had papers on their ecology published in national and international peer-reviewed, scientific journals; he is a former member (independent scientist) of the NSW Koala Recovery Team and more recently a member of the Federal Government's Expert Working Group on koala distribution and abundance. His primary research and consultancy interests focus on the development of landscape-scale habitat and population assessment techniques that can serve to increase the certainty of sustainable development and planning outcomes for koalas and other threatened species.

Further details including a *Curriculum Vitae*, supporting publications and list of koala themed consultancy projects completed over the last 10 years can be provided if required.

Appendix D Supplementary Biometric Plot Data

Plot Name	NPS	NOS	NMS	NGCG	NGCS	NGCO	EPC	NTH	OR	FL	Easting	Northing	Zone	Date	BVT 2014	Vegetation Zone
Plot 328	27	0	0	24	2	14	2	0	1	0	741775	6641277	55	23-10-17	NA409	Moderate/Good_Derived grassland
Plot 329	25	27	2	12	12	32	0	0	1	1	741141	6637100	55	24-10-17	NA219	Moderate/Good
Plot 330	20	0	0	22	0	42	4	0	0	0	741259	6637045	55	24-10-17	NA219	Moderate/Good_Derived grassland
Plot 331	31	13.1	5.3	0	40	8	0	3	1	30	753992	6599513	55	25-10-17	NA294	Moderate/Good
Plot 332	35	16.4	20.6	2	38	2	0	2	1	19	754642	6597867	55	25-10-17	NA294	Moderate/Good
Plot 333	15	50.5	0	0	40	8	0	0	1	2	759618	6612189	55	25-10-17	NA363	Moderate/Good
Plot 334	29	0	0	30	0	44	6	0	1	0	754955	6628941	55	27-10-17	NA338	Moderate/Good_Derived grassland
Plot 335	9	0	0	0	0	20	42	0	0	0	756800	6639680	55	25-10-17	NA307	Moderate/Good_Derived grassland
Plot 336	20	0	0	22	10	4	26	0	0	0	747158	6635015	55	26-10-17	NA117	Moderate/Good_Derived grassland

eco
logical
AUSTRALIA



HEAD OFFICE

Suite 4, Level 1
2-4 Merton Street
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

CANBERRA

Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

COFFS HARBOUR

35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

PERTH

Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

DARWIN

16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601
F 08 8941 1220

SYDNEY

Level 6
299 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9264 0717

NEWCASTLE

Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

ARMIDALE

92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

WOLLONGONG

Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

BRISBANE

Suite 1 Level 3
471 Adelaide Street
Brisbane QLD 4000
T 07 3503 7191
F 07 3854 0310

ST GEORGES BASIN

8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

NAROOMA

5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

MUDGEES

Unit 1, Level 1
79 Market Street
Mudgee NSW 2850
T 02 4302 1230
F 02 6372 9230

GOSFORD

Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897

1300 646 131

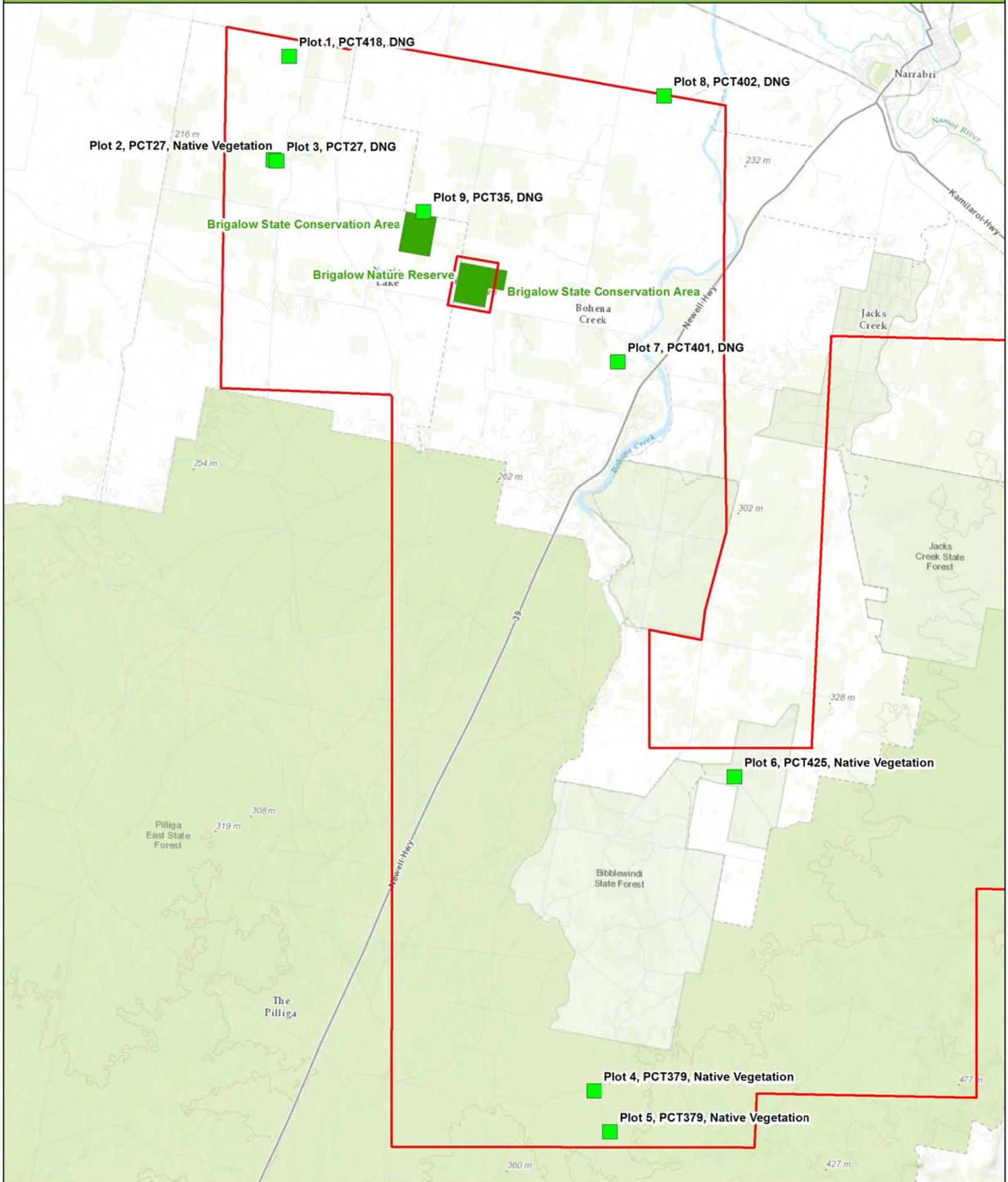
www.ecoaus.com.au



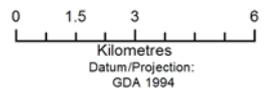
Appendix G

Supplementary biometric plots report

Additional Biometric Plots



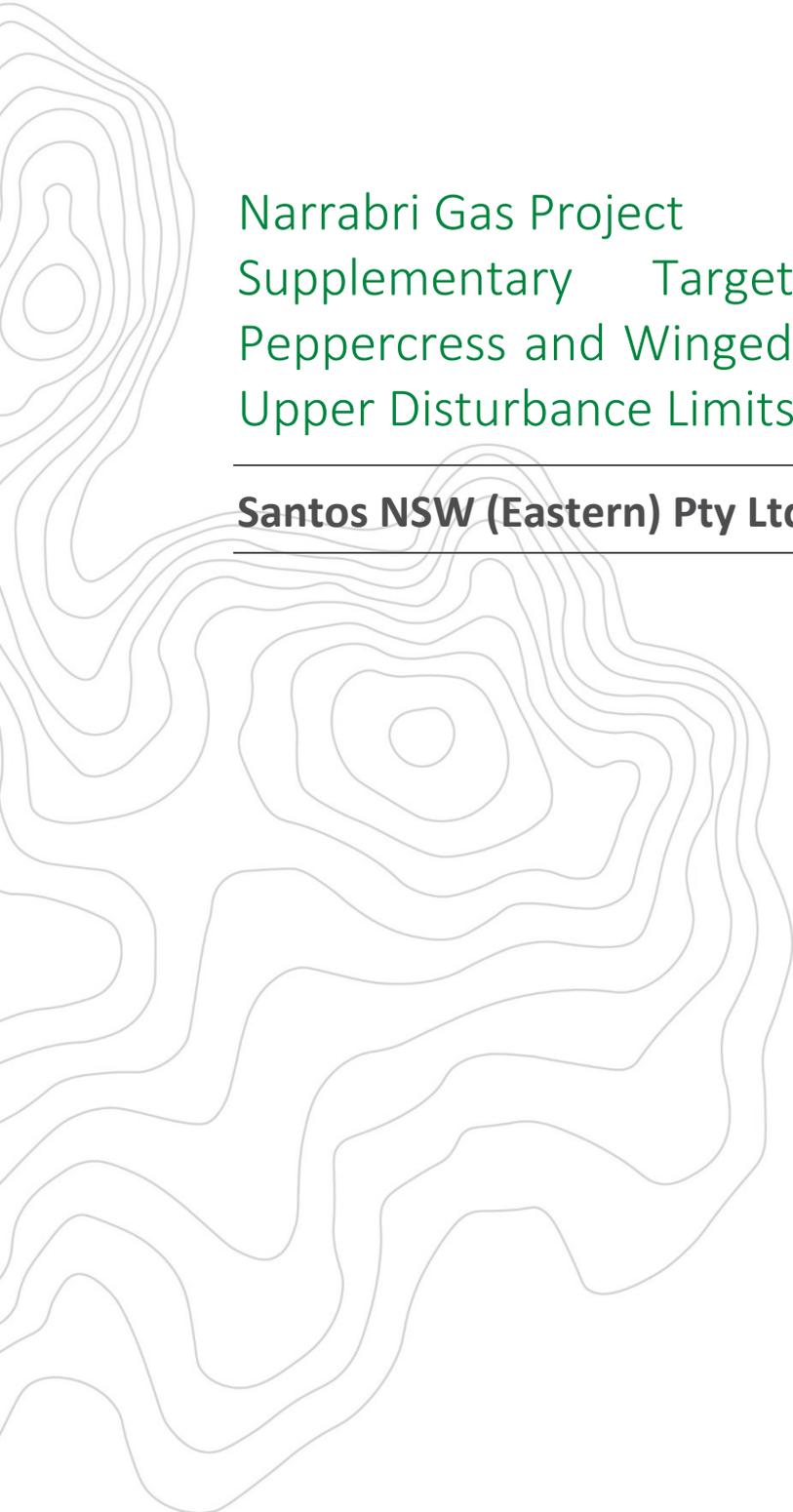
Legend
 Narrabri Gas Project Area
 Additional Biometric Plots





Appendix H

Supplementary targeted surveys for
Spiny Peppergrass and Winged Peppergrass
and revision of upper disturbance limits



Narrabri Gas Project
Supplementary Targeted Surveys for Spiny
Peppergrass and Winged Peppergrass and Revision of
Upper Disturbance Limits

Santos NSW (Eastern) Pty Ltd

Executive Summary

This report presents the findings of targeted surveys and population estimation for *Lepidium aschersonii* (Spiny Peppercross) and *Lepidium monoplocooides* (Winged Peppercross) within the Narrabri Gas project area.

L. aschersonii is listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *L. monoplocooides* is listed as Endangered under the BC Act and EPBC Act.

Targeted surveys for both species were undertaken between 23 and 27 October 2017 by two teams of ELA ecologists. Survey methods included a combination of random meander, 50 x 2m (100 m²) transects in suitable habitat, and 50 x 2m (100 m²) transects set at fixed distances to develop reliable population estimates. The three methods were tiered and subsequent methods were implemented as the detection of *L. aschersonii* and *L. monoplocooides* increased and the understanding of the abundance and localised habitat preferences of each species became apparent.

Population estimates were developed based on the total area of potential habitat for each species within the project area, the proportion of habitat occupied and the average density of plants per square metre.

Upper disturbance limits for each species were revised by assessing the total area of habitat potentially impacted by the Narrabri Gas Project, the proportion of habitat occupied and the average density of plants per square metre.

A total of 4,643 *L. aschersonii* individuals were identified at 113 discrete locations. A total of 2,268 *L. monoplocooides* individuals were identified at 65 discrete locations. Both *L. aschersonii* and *L. monoplocooides* were recorded within and outside of the project area.

An estimated 8,264,623 *L. aschersonii* occur within the project area based on an average density of 0.45 plants per square metre and an occupancy of 74% of suitable habitat. An estimated 218,265 *L. monoplocooides* occur within the project area based on an average density of 0.07 plants per square metre and an occupancy of 82% of suitable habitat.

The revised upper disturbance limit for *L. aschersonii* is 77,691 which represents 0.94% of the total population estimated within the project area. The revised upper disturbance limit for *L. monoplocooides* is 1,116 which represents 0.51% of the total population estimated within the project area. Both limits are well below the proportional impact of 1.55% assessed in the EIS (ELA 2016). The upper disturbance limits to these species are considered conservative and do not change the underlying assessment of impact to these species contained in Appendix J1 and Appendix J2 of the EIS

The results of this study have shown that there are considerable populations of both *L. aschersonii* and *L. monoplocooides* within the project area (up to an 8,000% increase on the known population of these species from the literature). Records and habitat for these species were also identified outside of the project area and therefore the populations of these species in the locality are likely to be much greater.

It is recommended that the listing status for both *L. aschersonii* and *L. monoplocooides* be reviewed in light of this new information.

Contents

1. Introduction.....	1
2. Background.....	1
2.1 <i>Lepidium aschersonii</i> (Spiny Peppercress) (BC Act – V; EPBC Act – V).....	1
2.2 <i>Lepidium monolocoides</i> (Winged Peppercress) (BC Act – E; EPBC Act– E).....	3
3. Methodology	8
3.1 Weather.....	8
3.2 Survey stratification	8
3.3 Methods	9
3.4 Population estimation	9
3.5 Upper disturbance limits	10
4. Results.....	12
4.1 <i>Lepidium aschersonii</i>	12
4.2 <i>Lepidium monolocoides</i>	12
4.3 Population estimation	13
4.4 Upper disturbance limits	19
5. Discussion.....	19
6. References.....	21

List of Figures

Figure 1: Distribution of <i>Lepidium aschersonii</i> in NSW.....	4
Figure 2: Distribution of <i>Lepidium aschersonii</i> in the Project Area	5
Figure 3: Distribution of <i>Lepidium monolocoides</i> in NSW	6
Figure 4: Distribution of <i>Lepidium monolocoides</i> in the Project Area	7
Figure 5: Survey area.....	11
Figure 6: Survey results	14
Figure 7: Paired <i>Lepidium aschersonii</i> transects in the west of the Project Area in road reserves (survey method 3).....	15
Figure 8: Fixed <i>Lepidium aschersonii</i> transects in Brigalow Nature Reserve and State Conservation Area (survey method 3)	16
Figure 9: <i>Lepidium monolocoides</i> transects in the north-east of the Project Area (fixed transects in the east running north-south).....	17
Figure 10: <i>Lepidium monolocoides</i> habitat in the Project Area	18

List of Tables

Table 1: Survey teams8
 Table 2: Potential habitat.....8
 Table 3: Population estimation13

Abbreviations

Abbreviation	Description
API	aerial photographic interpretation
BC Act	NSW Biodiversity Conservation Act 2016
BOM	Bureau of Meteorology
CI	Confidence Interval
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EPBC Act	Commonwealth Environment Protection and Biodiversity Conservation Act 1999
NPWS	National Parks and Wildlife Service
Santos	Santos NSW (Eastern) Pty Ltd

1. Introduction

This report presents the findings of targeted surveys and population estimation for *Lepidium aschersonii* (Spiny Peppergrass) and *L. monoplacoides* (Winged Peppergrass) within the Narrabri Gas Project area.

L. aschersonii is listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *L. monoplacoides* is listed as Endangered under the BC Act and EPBC Act.

In February 2017, the environmental impact statement (EIS) for the Narrabri Gas Project (the project) was submitted to the NSW Department of Planning and Environment for consideration as part of development application number SSD 14_6456. As part of the EIS a threatened flora modelling report was prepared to investigate threatened flora populations in the North-east Pilliga Forest (ELA 2015). The scope of the 2015 study was to provide statistically robust modelled estimates of population size and distribution, and outline habitat requirements for threatened flora populations in order to adequately address the potential impacts of the Narrabri Gas Project.

However, only a portion of the threatened species known to occur in the project area were detected during targeted flora surveys in sufficient numbers for modelling, namely *Diuris tricolor*, *Polygala linariifolia*, *Pterostylis cobarensis*, *Commersonia procumbens* and *Tylophora linearis*. These species are the subject of the 2015 modelling report. Furthermore, within the project area detailed mapping and population estimates have been previously developed for *Bertya opposens* and *Pomaderris queenslandica* (ELA 2016). However, modelling for *L. aschersonii* and *L. monoplacoides* was not undertaken at this time due to insufficient records and poor seasonal conditions during the surveys in which they were detected.

The ecological impact assessment for the EIS (ELA 2016) assumed a proportional loss to these species' known population within the project area, based on the average of impact to other threatened flora species' populations (approximately 1.55%). This resulted in very low impacts to these species (3 and 4 individuals for Spiny Peppergrass and Winged Peppergrass respectively) which were included in the upper disturbance limits for the Project as outlined in the EIS.

The proponent commissioned Eco Logical Australia Pty Ltd (ELA) to undertake this study to increase both the knowledge of the size and geographic extent of populations of Spiny Peppergrass and Winged Peppergrass within the project area, as well as determining realistic upper disturbance limits for these species as part of the Narrabri Gas Project EIS.

2. Background

2.1 *Lepidium aschersonii* (Spiny Peppergrass) (BC Act – V; EPBC Act – V)

L. aschersonii is an erect annual to perennial herb to 30 cm high, hairy and intricately branched, with the smaller branches spinescent. Plants become woody and more spinose in dry conditions. Basal leaves lobed, to 12 cm long, leaves reducing in size up the stem. Flowers small, borne in elongated clusters terminating in a spine. Fruit a 2-celled, flattened circular pod on a spreading stalk, 4 mm long and 2.5 mm wide, with slight wings in the upper half forming a small notch at the apex. *L. aschersonii*

is distinguished from other *Lepidium* species by the presence of tiny spines which give the mature plants an intricate appearance (OEH 2017a).

L. aschersonii has two main centres of distribution in NSW, one in the south near West Wyalong, Barmedman and Temora, and another in the north, which includes the populations within the project area (Figure 1). A population near Dubbo lies between these two main centres of distribution. Based on information provided in the National Recovery Plan (Carter 2010) the occurrences within the study area are highly significant as they are likely to be the largest known extant populations. They constitute the major proportion of extant records from the northern centre of distribution of the species in NSW. Most of the records from the southern centre of distribution in NSW are old (ALA 2017, OEH 2017b), underlining the importance of the northern populations. The species also occurs in Victoria and Western Australia, though it is not known whether it is extant in the latter (Carter 2010).

Prior to commencing this study, there were 56 records totalling more than 4,081 individuals for this species in the study area (ELA 2016, OEH 2017b) (Figure 2). These records were concentrated within and around Brigalow Nature Reserve and Brigalow State Conservation Area. Although the dry conditions were not favourable for detection of the species during fieldwork in the north-western part of the project area in 2013 and 2014, a total of 208 individuals (from four sub-populations) were recorded by ELA botanists (ELA 2016). Two of these subpopulations were from within Brigalow Nature Reserve, one from 3 km north and another from 4 km south east of Brigalow Nature Reserve (Figure 2).



Plate 1: *Lepidium aschersonii* in fruit

2.2 *Lepidium monolocoides* (Winged Peppergrass) (BC Act – E; EPBC Act– E)

L. monolocoides is an erect annual herb or perennial forb, 15-20 cm high, with angular and striped stems roughened with small warts. Leaves narrow and linear, mostly 2-7 cm long. Flowers small, borne in elongated clusters, the petals minute or absent. Fruit a 2-celled, flattened circular pod on a spreading stalk, 5 mm long and about 4 mm wide, with pointed wings extending to a narrow notch at the tip (OEH 2017a).

L. monolocoides occurs in north-western Victoria, South Australia and southern Queensland, and is widely distributed in semi-arid plains regions of NSW (Figure 3). The populations in the Pilliga region are located some 200 km distant from the nearest population. Although it has been recorded from a considerable number of sites, populations are often localised. In addition, some populations are extinct or their status uncertain. The National Recovery Plan (Mavromihalis 2010) estimates that the total population size is less than 3,000 plants each in Victoria and New South Wales, though populations from the Pilliga region were not known at that time.

L. monolocoides was not known from the project area prior to commencing survey work for the EIS, however it was recorded nearby in the Pilliga National Park and adjoining Pilliga State Conservation Area soon after (Bell, Hunter, & Montgomery 2012; ELA 2015). During vegetation sampling for the EIS, 258 individuals (from three subpopulations) were recorded by ELA botanists within the project area towards the northern boundary, south west of Narrabri (Figure 4).



Plate 2: *Lepidium monolocoides* in fruit

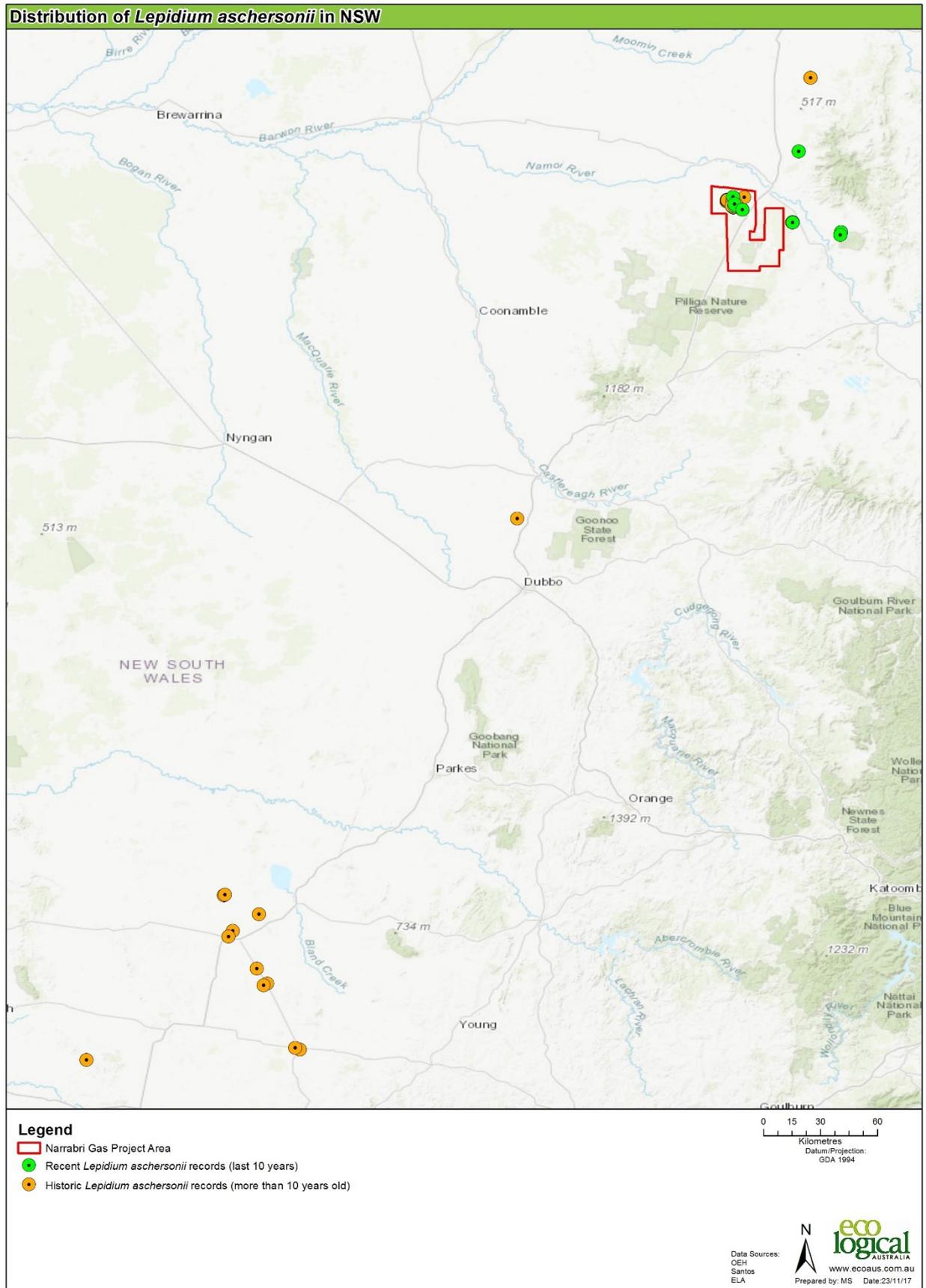


Figure 1: Distribution of *Lepidium aschersonii* in NSW

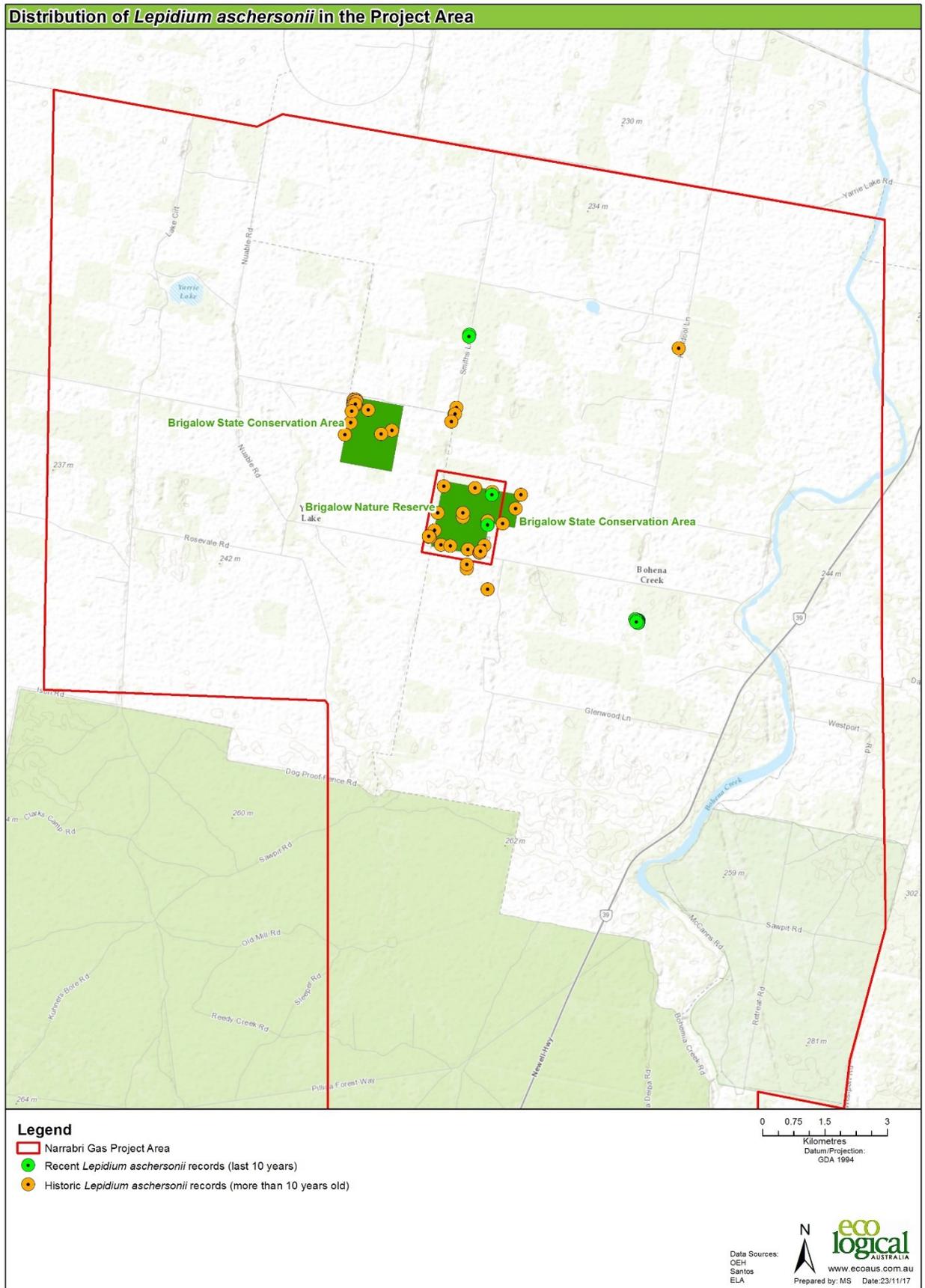


Figure 2: Distribution of *Lepidium aschersonii* in the Project Area

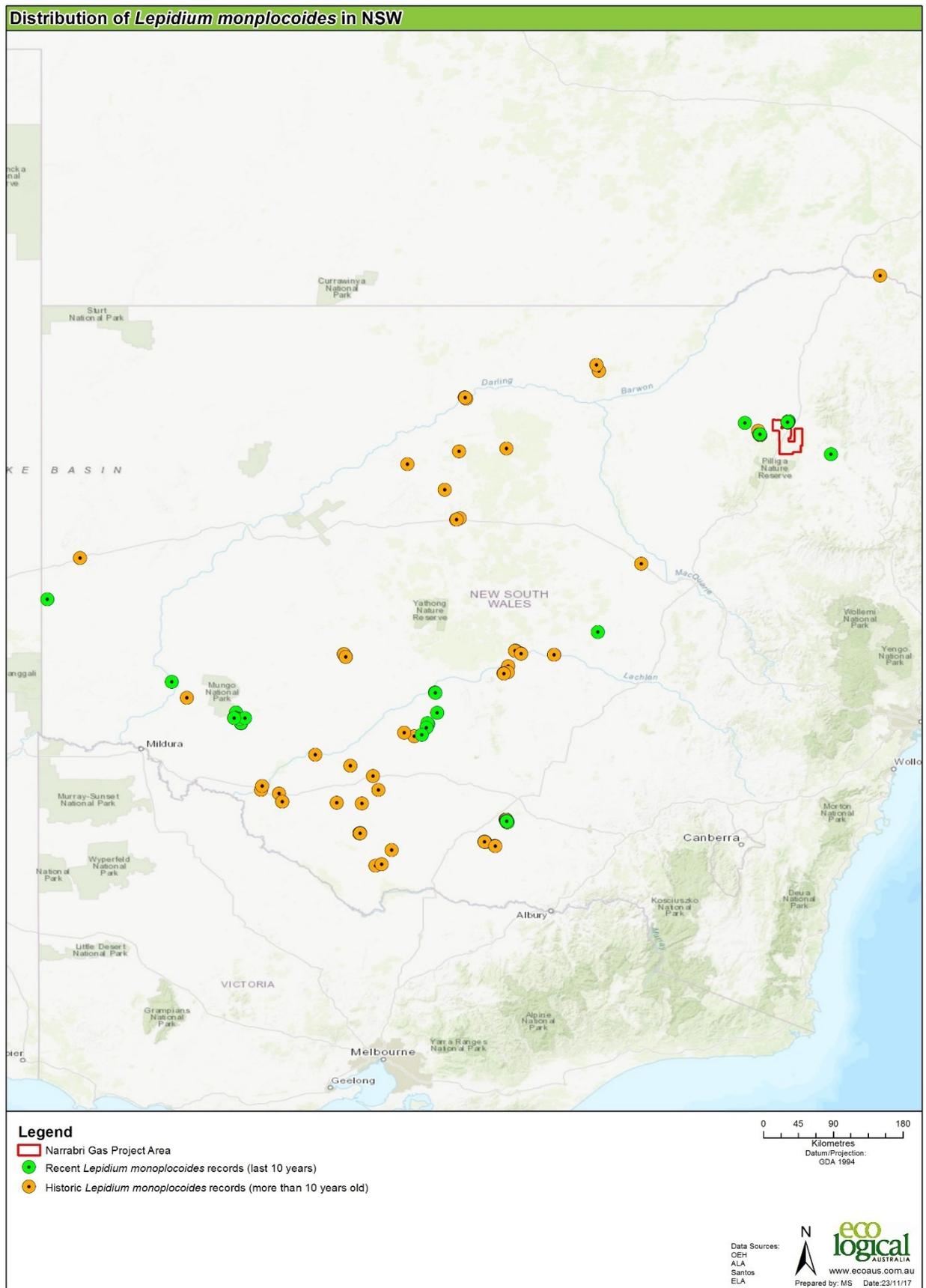


Figure 3: Distribution of *Lepidium monoplocoides* in NSW

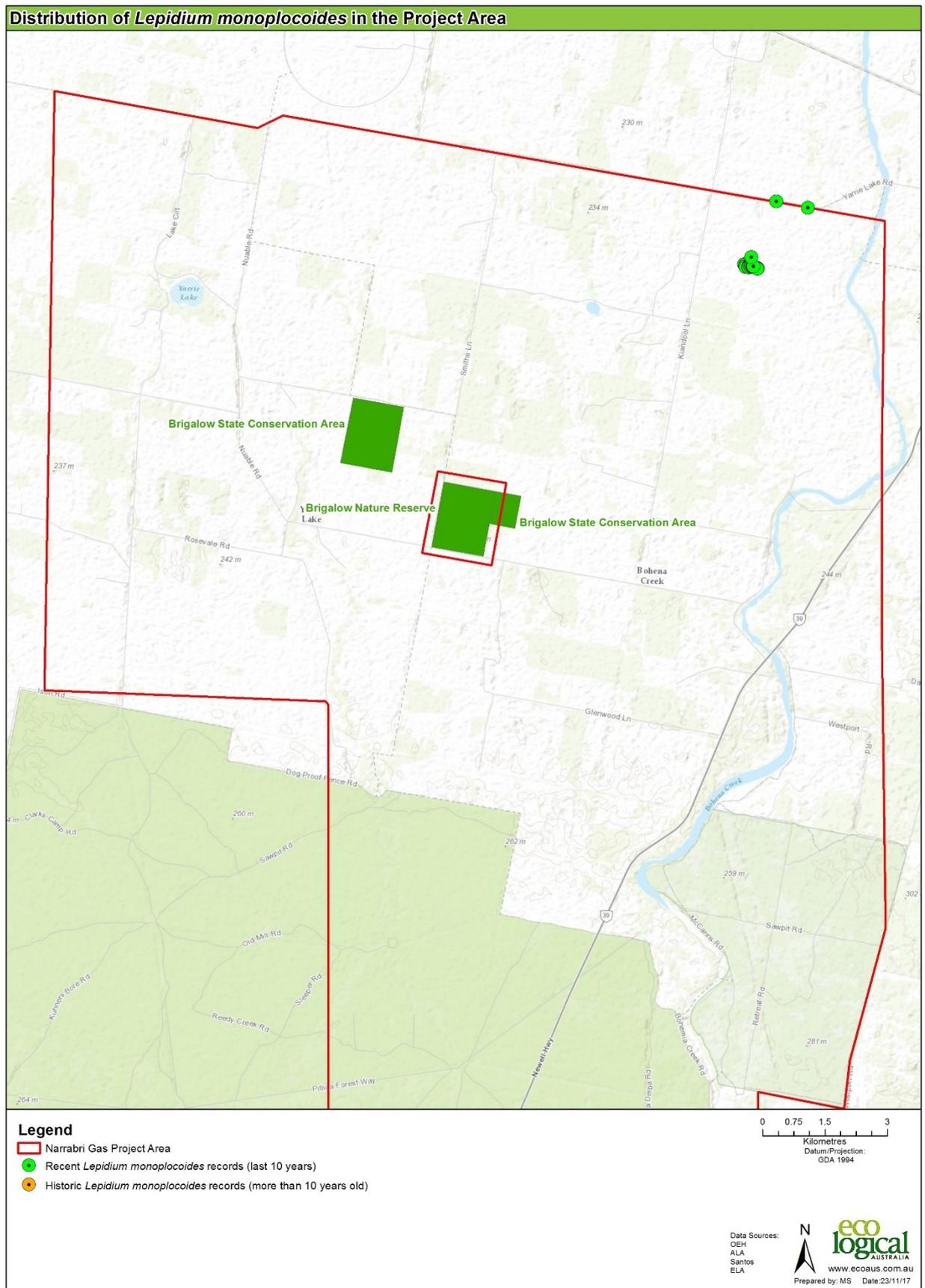


Figure 4: Distribution of *Lepidium monolocoides* in the project area

3. Methodology

Targeted surveys for *L. aschersonii* and *L. monoplocooides* were undertaken between 23 and 27 October 2017 by two teams of ELA ecologists (Table 1).

Table 1: Survey teams

	Team 1	Team 2
Lead	Martin Sullivan	Matthew Dowle
Assistant	Andrea Sabella	Kate Brodie

3.1 Weather

Weather during the surveys was generally fine and sunny with a daily maximum temperature of 34.6 degrees and a daily minimum temperature of 7.4 degrees (BOM 2017). 3.2 mm of rain was recorded overnight on Thursday 26 October 2017 (BOM 2017). Total rainfall in the preceding year was only slightly below average, however despite significant rainfall in autumn very little rainfall was recorded in the lead-up to the surveys (177 mm recorded between April and October compared to the average of 242 mm). Above average rainfall in October immediately preceding the surveys broke three months of well below average rainfall from late winter to early spring.

3.2 Survey stratification

Surveys for *L. aschersonii* and *L. monoplocooides* were stratified across the north-western portion of the project area and targeted public and private land within the north-western portion of the project area in suitable habitat. Potential habitat was defined prior to the commencement of surveys based on a review of existing knowledge including previous field surveys, vegetation mapping, recovery plans and relevant databases. A summary of potential habitat is provided in Table 2 and a map depicting areas which contain potential habitat is provided in Figure 5.

Table 2: Potential habitat

	<i>Lepidium aschersonii</i>	<i>Lepidium monoplocooides</i>
Plant Community Types	55 - Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	402 - Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion
	35 - Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	88- Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion
	88 - Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	397 - Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion
	397 - Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	

	<i>Lepidium aschersonii</i>	<i>Lepidium monolocoides</i>
Landscape position	Ridges of gilgai clays	Seasonally moist to waterlogged sites, on heavy fertile soils
Vegetation Condition	Native vegetation and derived grassland	Native vegetation and derived grassland
Tenure	Public and private land	Public and private land

3.3 Methods

Prior to the commencement of surveys, previously known populations (reference sites) of *L. aschersonii* and *L. monolocoides* were visited to ensure each species was detectable before commencing survey.

Private land access for surveys within the study area was negotiated by the proponent. Surveys were undertaken using three distinct methodologies:

1. Initial random meanders (Cropper 1993) through suitable habitat counting and recording individuals observed, estimating the localised area of occupancy and habitat type.
2. In areas of suitable habitat, 50 x 2 m (100 m²) transects were surveyed recording the precise number of individuals recorded and habitat type (n=40).
3. In five locations, a series of 50 x 2 m (100 m²) transects were surveyed at fixed distances apart in order to develop reliable population estimates. Locations included:
 - a. Road reserve in the west of the survey area (Forest Way and Hibbens Road). Paired sites were surveyed on either side of the road (n=18) with approximately 1,000 m between pairs
 - b. Brigalow Nature Reserve (n=5) at approximately 130 m spacing
 - c. Brigalow State Conservation Area (n=11) at approximately 130 m spacing
 - d. Private property to the south-west of Brigalow Nature Reserve (n=8) at approximately 100 m spacing
 - e. Private property in the north-east of the survey area (n=12) at approximately 130 m spacing

The three methods were tiered and subsequent methods were implemented as the detection of *L. aschersonii* and *L. monolocoides* increased and the understanding of the abundance and localised habitat preferences of each species became apparent. Survey method 3 was implemented in order to estimate the total population of these species within the project area.

3.4 Population estimation

Once a more detailed understanding of the abundance and localised habitat preferences for *L. aschersonii* and *L. monolocoides* was developed, population estimates using the data collected from the targeted surveys was undertaken. This required both the average density of plants per m² as well as the total extent of potential habitat within the project area.

For *L. aschersonii*, this was undertaken for all mapped Brigalow - Belah open forest / woodland within the project area. Due to the low number of records in other plant communities, population estimates were not developed for Belah woodland or Pilliga Box - White Cypress Pine - Buloke shrubby woodland.

For *L. monolocoides*, a map of potential habitat was developed based on known records and through aerial photographic interpretation (API) of key habitat features (clay pans) within and adjoining the

project area. Areas of mapped habitat were inspected directly during field surveys either on foot or through visual observation into adjoining lands.

A population estimation was then calculated using the following formula:

Total area of potential habitat X proportion of habitat occupied X average density of plants per m ²

The 95% confidence intervals were then applied to the population estimation to provide statistically robust bounds for the likely population within the Study Area.

3.5 Upper disturbance limits

Following the estimation of population size, revised upper disturbance limits for *L. aschersonii* and *L. monoplcoides* were developed. These were determined through the following formula:

Total area of habitat impacted X proportion of habitat occupied X average density of plants per m ²
--

The total area of habitat impacted was taken directly from the upper disturbance limits for the respective plant community types for each species as detailed in the EIS (ELA 2016).

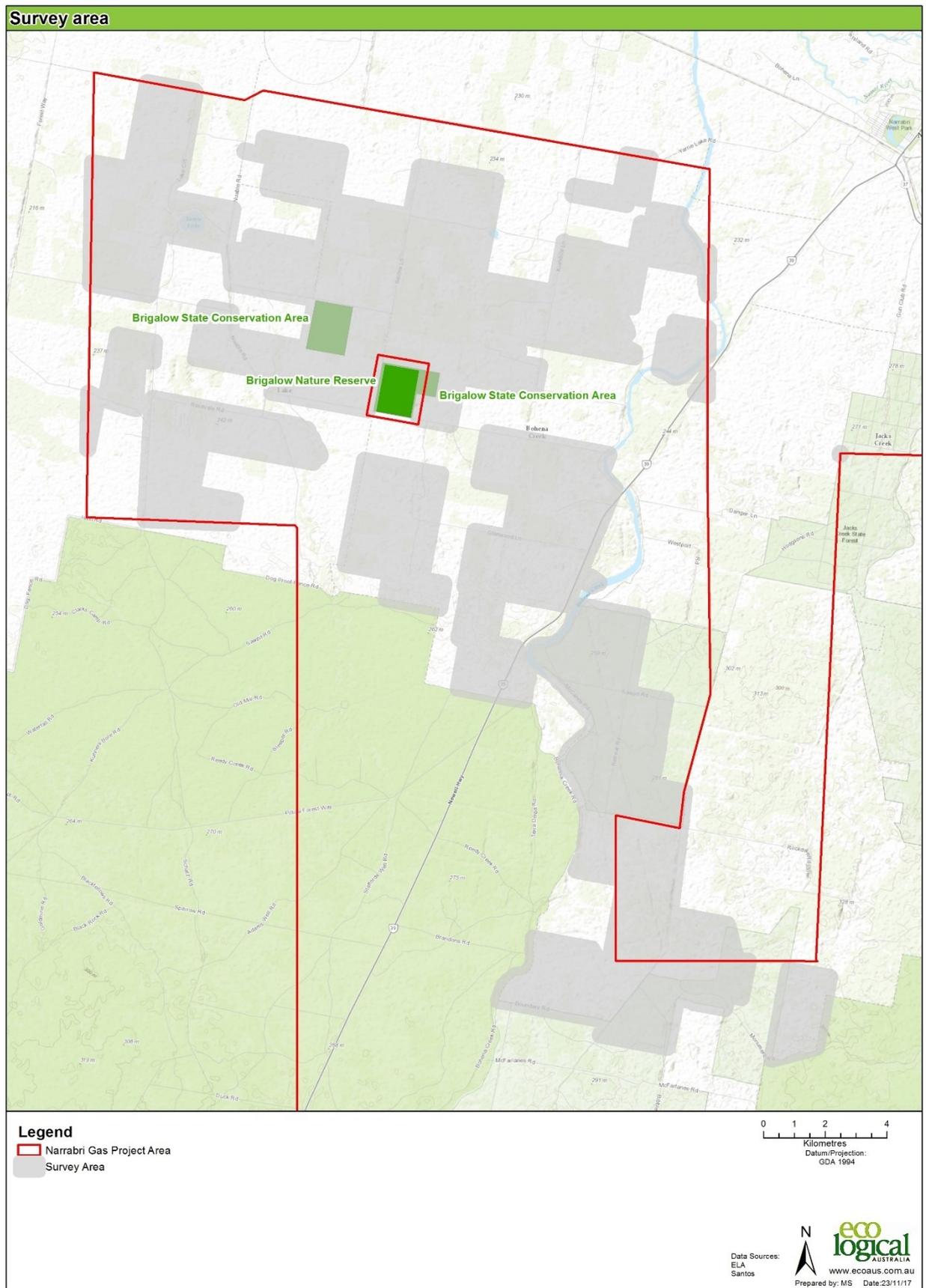


Figure 5: Survey area

4. Results

Both *L. aschersonii* and *L. monoplocooides* were confirmed present at reference sites prior to the commencement of survey, with *L. aschersonii* having largely completed its lifecycle and now only consisting of woody stems, spinose branches and occasional fruits, while *L. monoplocooides* was observed from seedlings, flowering plants to plants in full fruit.

A total of 4,643 *L. aschersonii* individuals were identified at 113 discrete locations including 61, 50 x 2 m (100 m²) transects (Figure 6). A total of 2,268 *L. monoplocooides* individuals were identified at 65 discrete locations including 31, 50 x 2 m (100 m²) transects (Figure 6). Both *L. aschersonii* and *L. monoplocooides* were recorded within and outside of the project area.

4.1 *Lepidium aschersonii*

L. aschersonii was consistently recorded in high abundance in Brigalow - Belah open forest / woodland on ridges of gilgai clays. Very few individuals were recorded in Belah woodland and Pilliga Box - White Cypress Pine - Buloke shrubby woodland. No individuals were recorded in Poplar Box - White Cypress Pine shrub grass tall woodland. This supports the current understanding of this species' preference for the habitat as described in the literature.

L. aschersonii was recorded in 71% of all transects surveyed (n=70) with an average density of 0.43 individuals per m² (95% CI: 0.30 - 0.56). In Brigalow - Belah open forest / woodland this increased to 79% of all transects surveyed (n=62) and had a slightly higher average density of individuals recorded of 0.45 per m² (95% CI: 0.32 - 0.60).

When considering only those transects surveyed at fixed distances (survey method 3, Figure 7 and Figure 8), *L. aschersonii* was recorded in 74% of all transects surveyed (n=38) with an average density of 0.45 individuals per m² (95% CI: 0.27 - 0.64). The similarity in averages (and confidence intervals) between the analysis of all transects (survey method 2 and 3 combined) and transects surveyed at fixed distances (survey method 3 only) highlights the consistent occurrence of this species across areas of potential habitat. The analysis from transects surveyed at fixed distances is likely to be most useful in determining an accurate population estimate, as it includes areas of habitat and non-habitat at the micro-habitat scale, rather than bringing in potential observer bias from survey method 2 (i.e. random allocation of transects compared with selected allocated of transects).

4.2 *Lepidium monoplocooides*

L. monoplocooides was consistently recorded in high abundance in Mugga Ironbark - White Cypress Pine - gum tall woodland on the edges of clay pans. Relatively few individuals were recorded in Pilliga Box - White Cypress Pine - Buloke shrubby woodland and Poplar Box - White Cypress Pine shrub grass tall woodland. This supports the current understanding of this species' preference for the habitat as described in the literature. Interestingly *L. monoplocooides* was also recorded in areas previously subject to pasture improvement where suitable clay pan habitat existed.

L. monoplocooides was recorded in 86% of all transects surveyed (n=35) with an average density of 0.45 individuals per m² (95% CI: 0.03 - 0.86) (Figure 9). Due to one transect with a very high number of individuals recorded (724), the reported average density above resulted in a wide 95% confidence

interval. When this transect is removed, the average density is approximately half at 0.25 individuals per m² with a much lower confidence interval of 0.11 - 0.39.

When considering only those transects surveyed at fixed distances (survey method 3), *L. monolocoides* was recorded in 82% of all transects surveyed (n=11) with an average density of individuals of 0.07 per m² (95% CI:0.01 - 0.14). As this species does not occur consistently throughout areas of potential habitat (being generally restricted to the edges of clay pans), the analysis from transects surveyed at fixed distances (survey method 3) is likely to be more useful in providing an accurate population estimate across areas of habitat, as it includes areas of habitat and non-habitat at the micro-habitat scale.

4.3 Population estimation

An estimated 8,264,623 *L. aschersonii* occur within the project area based on an average density of 0.45 plants per m² (95% CI: 0.27-0.64) and an occupancy of 74% of suitable habitat (Table 3).

An estimated 218,265 *L. monolocoides* occur within the project area based on an average density of 0.07 plants per m² (95% CI: 0.01-0.14) and an occupancy of 82% of suitable habitat (Table 3).

Table 3: Population estimation

	<i>Lepidium aschersonii</i>	<i>Lepidium monolocoides</i>
Average plants per m ²	0.45	0.07
Average plants per m ² (lower 95% CI)	0.27	0.01
Average plants per m ² (upper 95% CI)	0.64	0.14
Total habitat in Project Area (ha)	2,468	371
% occupancy	74%	82%
Estimated area occupied (ha)	1,819	304
Abundance mean abundance	8,264,623	218,265
Abundance estimate (lower 95% CI)	4,920,221	24,696
Abundance estimate (upper 95% CI)	11,609,025	411,835

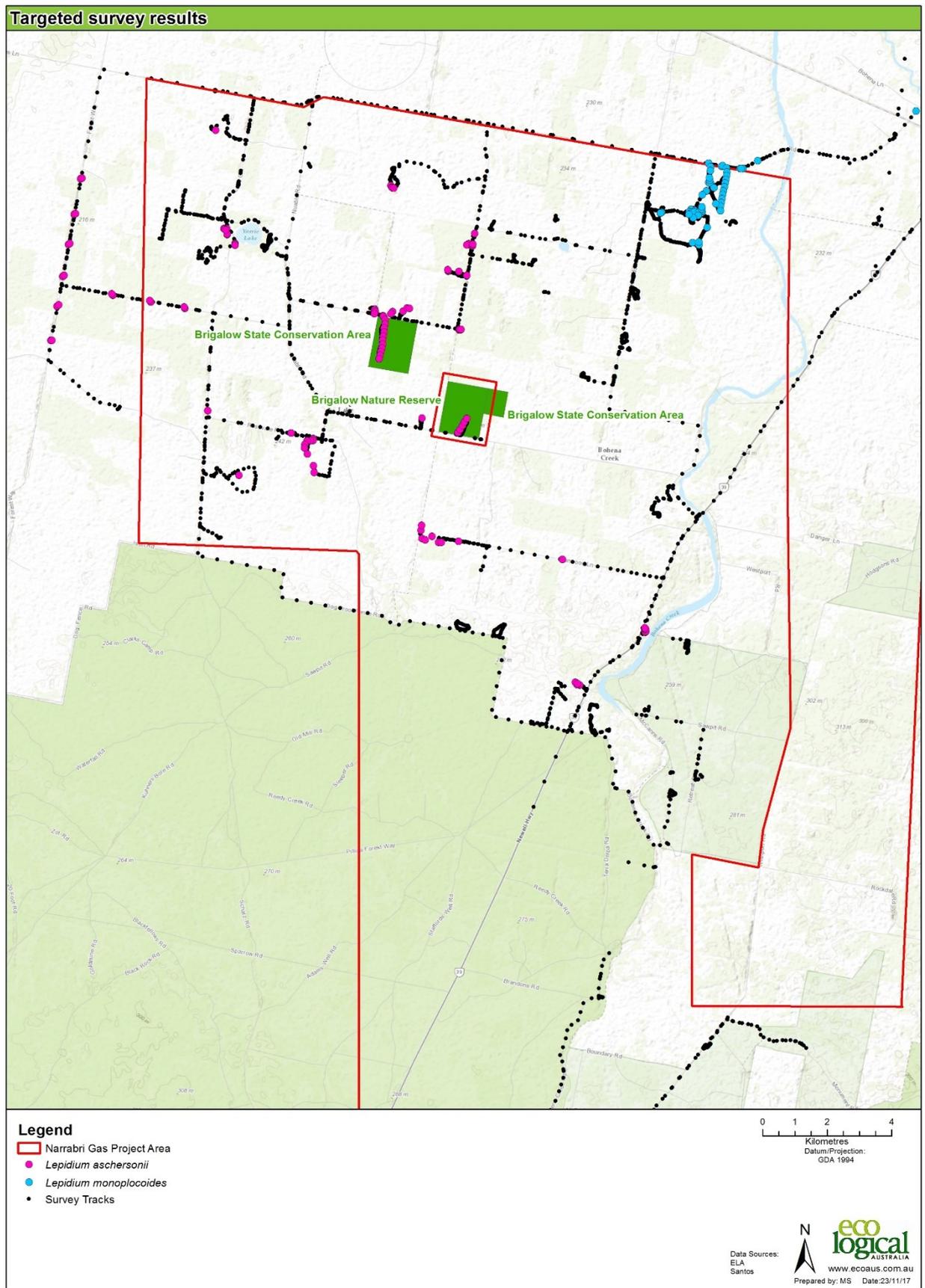


Figure 6: Survey results

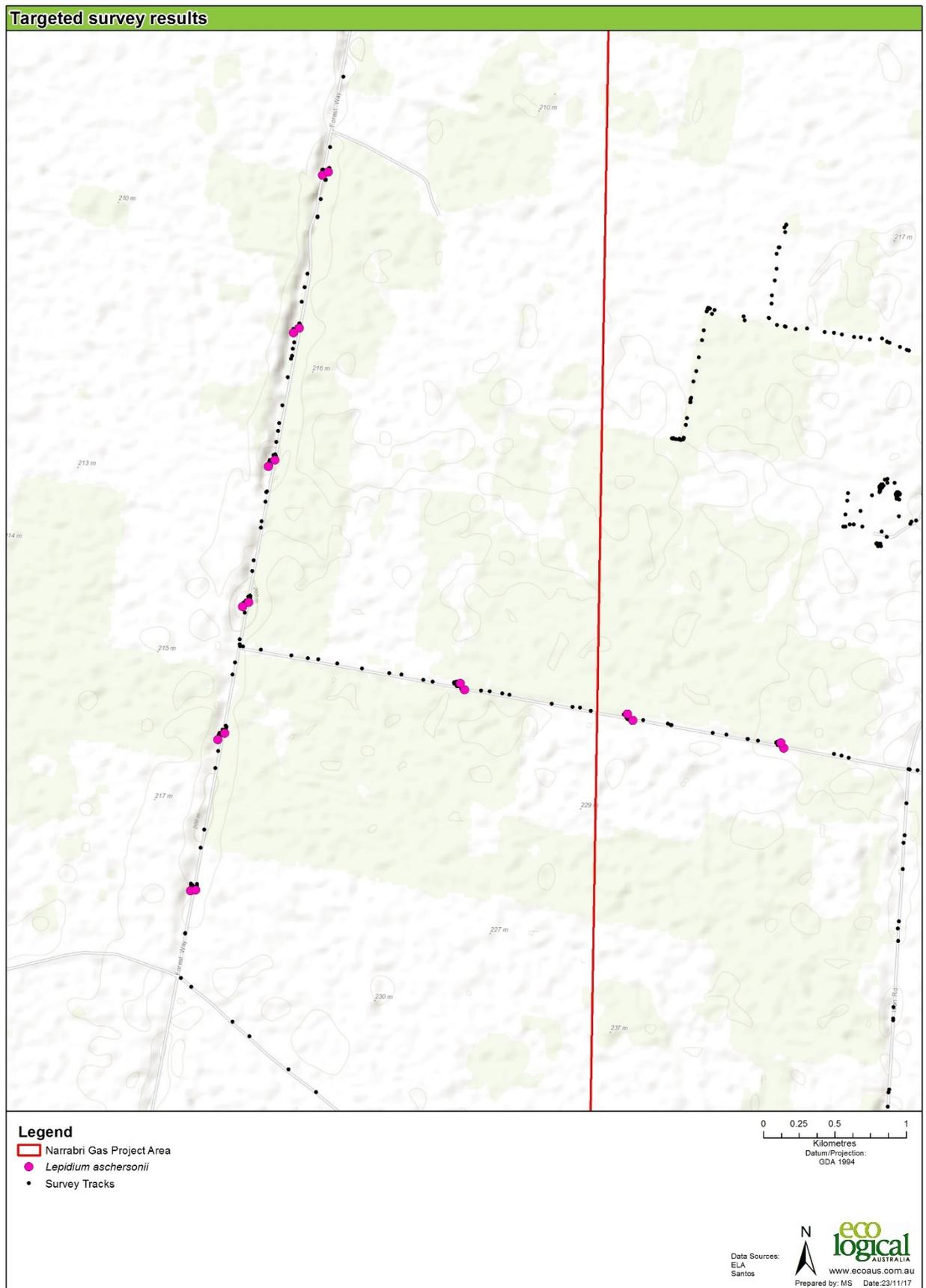


Figure 7: Paired *Lepidium aschersonii* transects in the west of the project area in road reserves (survey method 3)

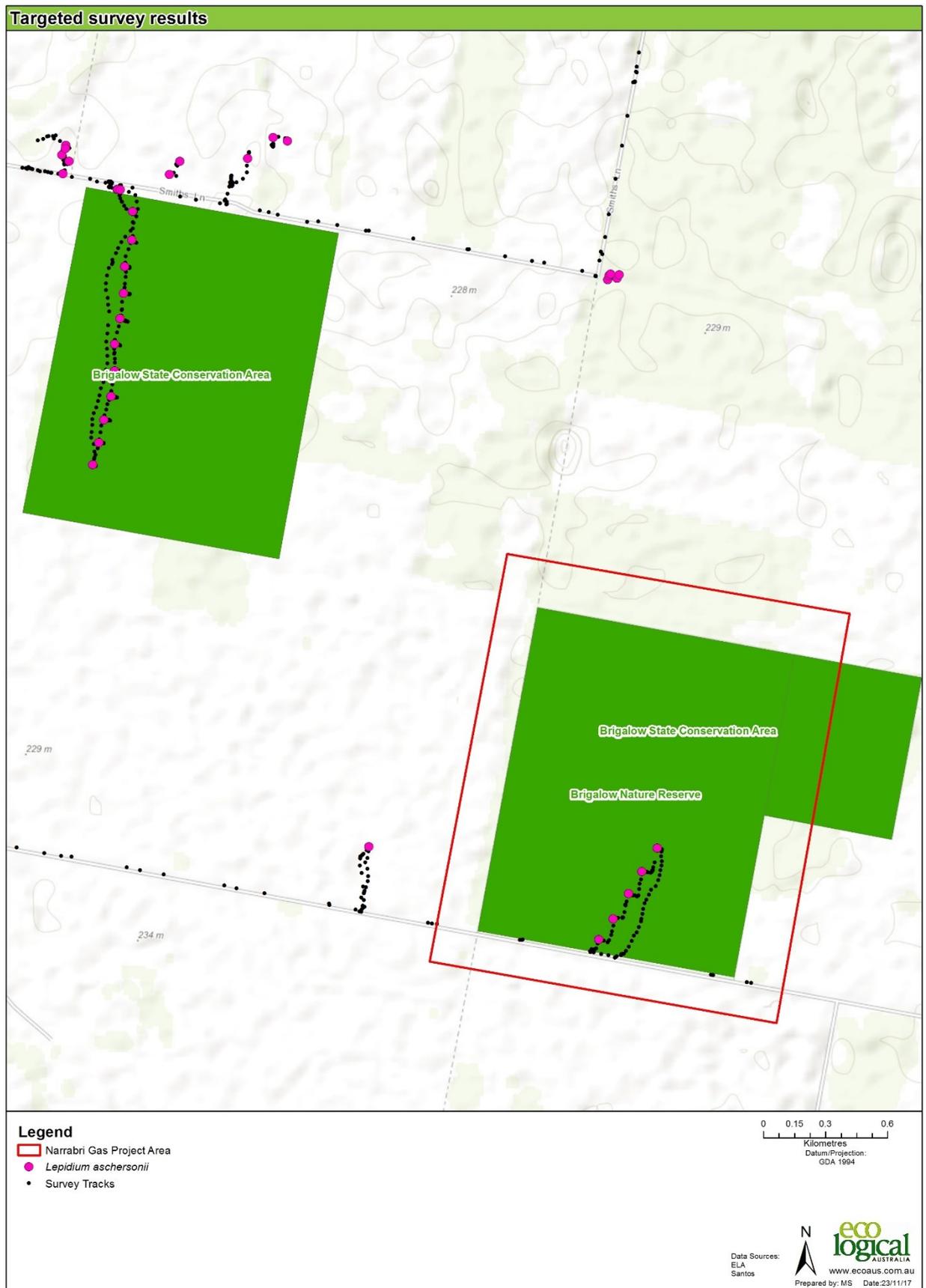


Figure 8: Fixed *Lepidium aschersonii* transects in Brigalow Nature Reserve and Brigalow State Conservation Area (survey method 3)

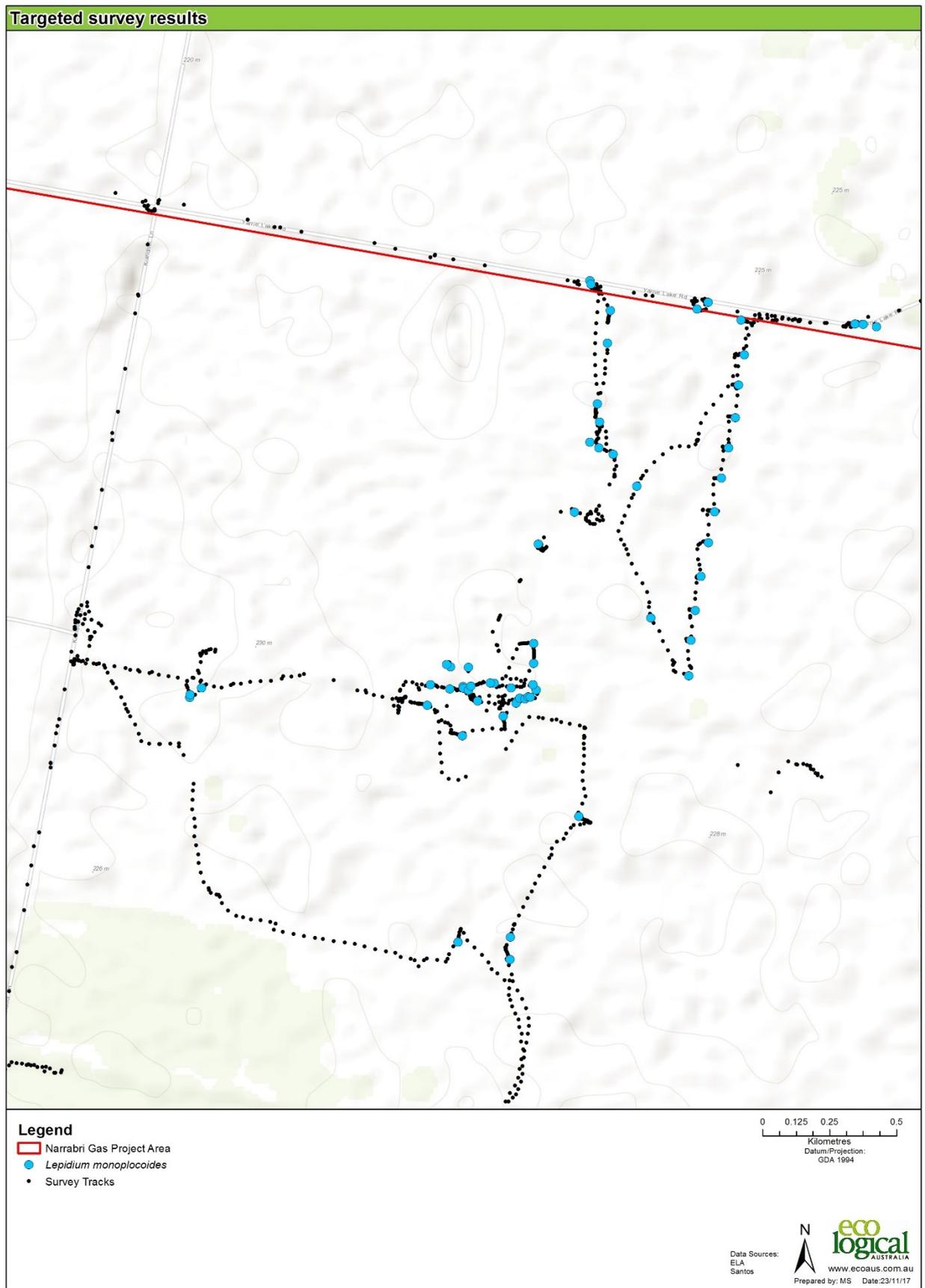


Figure 9: *Lepidium monoplocoides* transects in the north-east of the project area (fixed transects in the east running north-south)

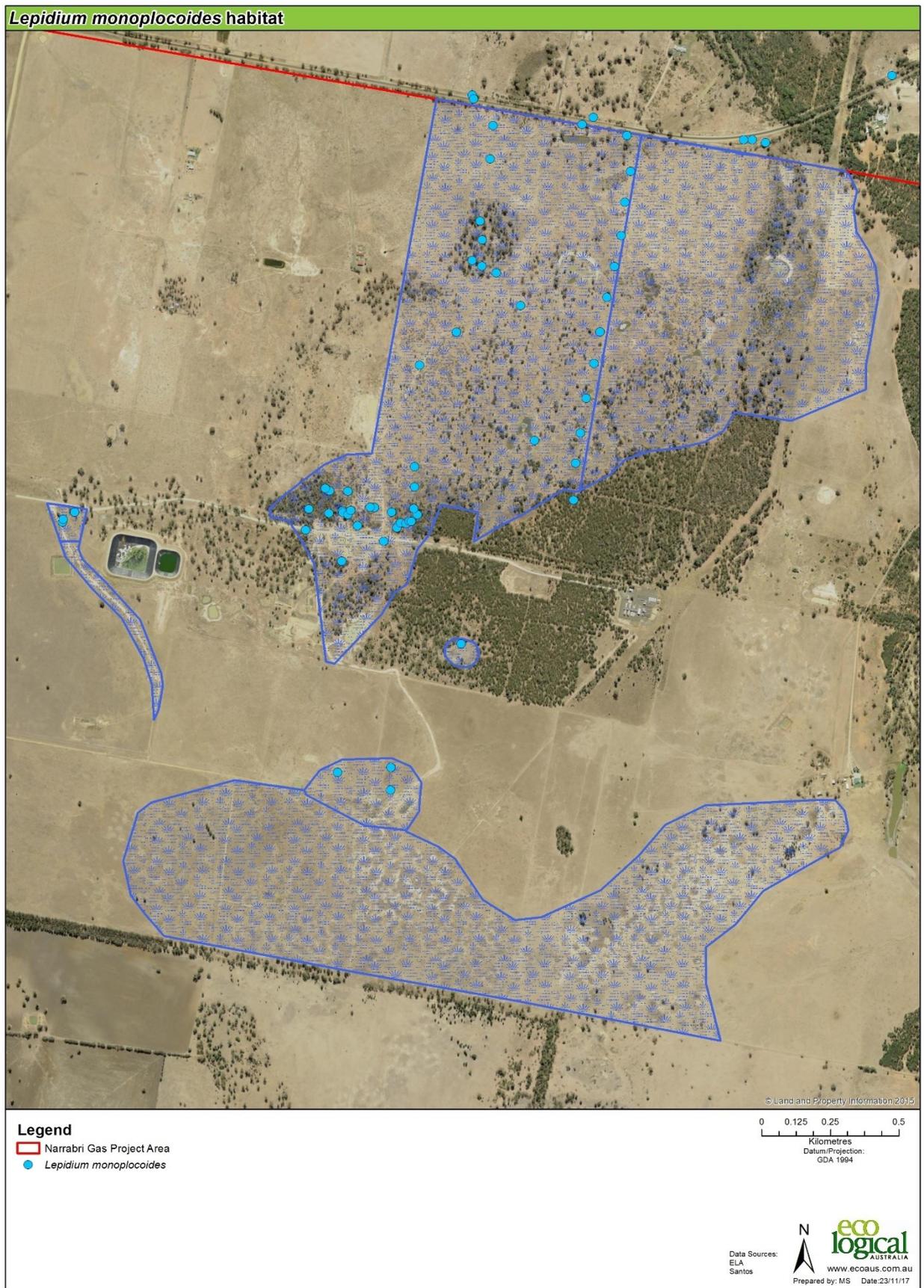


Figure 10: *Lepidium monolocoides* habitat in the project area

4.4 Upper disturbance limits

The revised upper disturbance limit for *L. aschersonii* is 77,691 which represents 0.94% of the total population estimated within the project area. The revised upper disturbance limit for *L. monoplocooides* is 1,116 which represents 0.51% of the total population estimated within the project area.

Species	Project Area			Direct and Indirect Impact			Proportion		
	Estimated mean abundance	Lower 95% CI	Upper 95% CI	Impact (number of individuals)	Lower 95% CI	Upper 95% CI	Impact (%)	Lower 95% CI	Upper 95% CI
<i>Lepidium aschersonii</i>	8,264,623	4,920,221	11,609,025	77,691	46,252	109,130	0.94%	0.94%	0.94%
<i>Lepidium monoplocooides</i>	218,265	24,696	411,835	1,116	126	2,107	0.51%	0.51%	0.51%

5. Discussion

This report has presented the findings of targeted surveys and population estimation for *L. aschersonii* and *L. monoplocooides* within the Narrabri Gas Project area. The population estimates have been developed using a rigorous, repeatable and defensible scientific methodology.

The results of this study have shown that there are considerable populations of both *L. aschersonii* and *L. monoplocooides* within the Narrabri Gas Project area. Records and habitat for these species were also identified outside of the project area and therefore the populations of these species in the locality are likely to be much greater.

Significant populations of *L. aschersonii* occurs within both the Brigalow Nature Reserve and Brigalow State Conservation Area. Based on the average density of 0.45 individuals per m², there are likely to be more than 2,000,000 individuals in NPWS estate alone. This represents approximately 25% of the estimated population within the project area. A substantial proportion of the remaining population occurs either on private land, or in council managed road reserves.

L. monoplocooides was only recorded on private land and in council managed road reserves, with no populations detected within NPWS estate in the project area. This species is known to occur in Pilliga National Park and Pilliga State Conservation Area, however the total population in these reserves is unknown.

The National Recovery Plan for *L. aschersonii* estimated the total population size of this species in NSW at approximately 10,000 individuals and the national population at between 25,000 and 100,000 plants (Carter2010). The estimated 8,264,623 *L. aschersonii* in the project area represents an 8,000% increase in the known population of this species. Even at the lower end of the estimation, there is likely to have been a 5,000% increase in the known population of this species. This report represents a significant change to the known population of this species, and likely warrants a review of the listing status of this species considering its total abundance and security of tenure.

The National Recovery Plan for *L. monoplacoides* estimated the total population size of this species in NSW at less than 3,000 plants, and the national population at less than 3,000 plants (Mavromihalis 2010). The estimated 218,265 *L. monoplacoides* in the project area represents a 7,000% increase in the known population of this species. Even at the lower end of the estimation, there is likely to have been an 800% increase in the known population of this species. This study represents a significant change to the known population of this species. This species is not known from NPWS estate in the project area and there are very few records from NPWS estate in NSW. It is likely that this species also occurs widely in the locality in areas of suitable habitat which are clearly identifiable on aerial photography. Further work in the locality, including areas outside of the project area is likely to substantially increase the known population of this species. The listing status of this species may warrant review following the findings of this report.

Revised upper disturbance limits for both *L. aschersonii* and *L. monoplacoides* for the development of the Narrabri Gas Project have been provided. Both limits are well below the proportional impact of 1.55% identified in the EIS (ELA 2016). The upper disturbance limits to these species are considered conservative and do not change the underlying assessment of impact to these species contained within the EIS.

6. References

- Atlas of Living Australia 2017. Occurrence downloads for *Lepidium aschersonii* and *Lepidium monolocoides* [Web Page]. Retrieved November 23, 2017, from <https://www.ala.org.au/>
- Bureau of Meteorology 2017. Narrabri, New South Wales October 2017 Daily Weather Observations [Web Page]. Retrieved November 23, 2017, from <http://www.bom.gov.au/climate/dwo/201710/html/IDCJDW2093.201710.shtml>
- Bell, D. M., Hunter, J. T., & Montgomery, L. 2012. Ephemeral wetlands of the Pilliga Outwash, northwest NSW. *Cunninghamia*, 12(3), 181–190. Retrieved from http://www.rbg Syd.nsw.gov.au/science/Scientific_publications/cunninghamia/contents_by_volume/volume_12#twelvethree
- Carter, O. 2010. *National Recovery Plan for the Spiny Peppergrass Lepidium aschersonii*. Melbourne
- Cropper, S.C. 1993. *Management of Endangered Plants*. CSIRO Publications Victoria.
- Eco Logical Australia 2015. *North-east Pilliga Forest Threatened Flora Modelling*. Prepared for Santos NSW (Eastern) Pty Ltd.
- Eco Logical Australia 2016. *Narrabri Gas Project: Ecological Impact Assessment*. Prepared for Santos NSW (Eastern) Pty Ltd.
- Mavromihalis, J. 2010. *National Recovery Plan for the Winged Peppergrass Lepidium monolocoides*. Melbourne.
- Office of Environment and Heritage 2017a. *Threatened Species Profiles* [Web Page]. Retrieved from http://threatenedspecies.environment.nsw.gov.au/tsprofile/browse_scientificname.aspx
- Office of Environment and Heritage 2017b. *NSW BioNet Atlas of NSW Wildlife* [Web Page]. Retrieved November 23, 2017, from <http://www.bionet.nsw.gov.au/>

