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A1: Reviewed previous surveys

Unique code	Author	Report Name	Survey type
48	(Alison Hunt & Associates Pty Ltd, 2011)	CNC Project management Eastern Star Gas Narrabri to Wellington Gas Pipeline. Draft Ecological Assessment	Flora & Fauna
45	(Carlton & Paull, 2002)	Pilliga State Forest Flora and Fauna Survey 14 to 19 November 2001	Fauna
25	(ELA, 2011a)	Bibblewindi Coal Seam Gas (CSG) Pilot: Addendum to the Dewhurst and Bohena Pilots Ecological Assessment	Flora & Habitat
27	(ELA, 2011b)	Ecological Investigations for Tintsfield 8 and Bibblewindi 30 core holes	Flora & Habitat
35	(ELA, 2011c)	Dewhurst and Bohena Pilots: Ecological Assessment	Flora & Fauna
26	(ELA, 2011d)	Narrabri Gas Project - Addendum to the Ecological Assessment: Spring micro-siting survey and assessment	Flora & Habitat
34	(ELA, 2011e)	Seismic line survey	Flora
28	(ELA, 2012a)	Narrabri Gas Project - Analysis of rehabilitation from exploratory works	Flora & Habitat
30	(ELA, 2012b)	Narrabri Gas Project - Targeted threatened flora survey	Flora
33	(ELA, 2013b)	Dewhurst Gas Exploration Pilot Expansion. Ecological Assessment for the expansion of operations at Dewhurst 13 - 18H and Dewhurst 26 - 31 pilots	Flora & Fauna
31	(ELA, 2013e)	Narrabri Gas Development Project - Second year analysis of rehabilitation from exploration activities	Flora & Rehabilitation monitoring
29	(ELA, 2013f)	Narrabri Gas Project – Bibblewindi Water Treatment Facility - Forest Health Assessment	Flora Health
32	(ELA, 2014a)	Energy NSW Coal Seam Gas Exploration and Appraisal Program: Pre-clearing and clearing report	Flora & Fauna
47	(ELA, 2014b)	ENSW Core hole and 4 Spot Pilot Environmental Assessment Ecological Impact Assessment for Bibblewindi 34 Core hole and Dewhurst 4-Spot Pilot (32, 33, 36 & 37)	Flora & Fauna
6	(Idyll Spaces Environmental Consultants, 2005)	PEL 238 Coal Seam Gas Flora Survey	Flora
7	(Idyll Spaces Environmental Consultants, 2006)	Flora Survey for propsed evaporation pond, PEL 238 Coal Seam Gas Project	Flora
8	(Idyll Spaces Environmental Consultants, 2007)	Flora Survey for proposed gas pipeline, PEL 238 Coal Seam Gas project	Flora
9	(Idyll Spaces Environmental Consultants, 2009)	Flora assessment of proposed seismic surveys EC09 & EB09	Flora
10	(Idyll Spaces Environmental Consultants, 2010)	Flora assessment : proposed drilling of two exploratory core holes, Dewhurst 20 & 21	Flora
42	(Kavanagh & Stanton, 2009)	Conserving Barking Owls in the Pilliga Forests	Fauna
43	(Kavanagh, Stanton, & Brassil, 2007)	Koalas continue to occupy their previous home-ranges after selective logging in Callitris-Eucalyptus forest	Fauna
1	(Kendall and Kendall Ecological Consultants, 2005)	Fauna Study PEL 238 Coal Seam Gas	Fauna
2	(Kendall and Kendall Ecological Consultants, 2006)	Fauna Study Proposed Water Management Facility at Bibblewindi PEL 283 Coal Seam Gas	Fauna
3	(Kendall and Kendall Ecological Consultants, 2007)	Proposed Gas Pipeline, PEL 238 Coal Seam Gas Project. Fauna Assessment	Fauna
4	(Kendall and Kendall Ecological Consultants, 2009)	Fauna Impact Assessment for Proposed Seismic Surveys - PEL 238 Coal Seam Gas Project	Fauna
5	(Kendall and Kendall Ecological Consultants, 2010)	PEL 238 Coal Sea Gas Project. Proposed Drilling of Two Exploratory Core Holes. Dewhurst 20 & 21. Fauna Assessment	Fauna
11	(Landmark Ecological Services & The Wilderness Society, 2012)	The Biodiversity values of Pilliga East Forest and the Threats Posed by Coal Seam Gas Mining 2011 - 2011	Flora & Fauna
46	(Milledge, 2004)	Large owl territories as a planning tool for vertebrate fauna conservation in the forests and woodlands of eastern Australia	Fauna

Unique code	Author	Report Name	Survey type
44	(NPWS, 2000a)	Brigalow Belt South: Regional Assessment (Stage 1) - Report on Preliminary Fauna Survey of Pilliga and Goonoo Forests, November 1999 to January 2000	Fauna
40	(Paull, 2002)	Community Data Search and Biodiversity Survey of the Brigalow Belt South: NSW Western Regional Assessments	Fauna
39	(Paull, 2009)	Habitat and post-fire selection of the Pilliga Mouse *Pseudomys pilligaensis* in Pilliga East State Forest	Fauna
12	(RPS, 2012a)	Due Dilligence Ecological Appraisal for a Proposed CSG exploration site, 'Kiandool', Narrabri	Flora & Fauna
13	(RPS, 2012b)	Ecological Assessment: Galathera 1 Core Hole - PEL 238, Gunnedah Basin, NSW	Flora & Fauna
14	(RPS, 2012c)	Ecological Assessment: Leewood - Produced Water and Brine Management Project (Phase 1)	
15	(RPS, 2012d)	Preliminary Ecological Assessment: Dewhurst 20 and 21 - PEL 238, Narrabri	Flora & Fauna
16	(RPS, 2013a)	Ecological Assessment: Dewhurst Northern Water and Gas Flow Lines - PEL 238 and PAL 2, Gunnedah Basin, NSW	Flora & Fauna
17	(RPS, 2013b)	Ecological Assessment: Bibblewindi 30 Core Hole, Narrabri	Flora & Habitat
18	(RPS, 2013c)	Ecological Assesment: Dewhurst 13 - 18 Gathering System, Narrabri	Flora & Habitat
19	(RPS, 2013d)	Ecological Assessment: Dewhurst 22 - 25 - PEL 238, Narrabri	Flora & Fauna
20	(RPS, 2013e)	Ecological Assessment: Dewhurst 26 - 29 Pilot Wells - PEL 238, Narrabri	Flora & Fauna
21	(RPS, 2013f)	Ecological Assessment: Dewhurst Southern Water and Gas Flow Lines - PEL 238 and PAL 2, Narrabri	Flora & Fauna
22	(RPS, 2013g)	Ecological Assessment: Narrabri West Core Hole - PEL238, Gunnedah Basin, NSW	Flora & Habitat
23	(RPS, 2013i)	Preliminary Ecological Assessment: Dewhurst 21 - PEL 238, Narrabri	Flora & Habitat
41	(Tokushima et al., 2008)	Ecology of the rare but irruptive Pilliga mouse (Pseudomys pilligaensis). I. Population fluctuations and breeding season	Fauna

A2: Field team

Field staff	Specialisation	Qualifications
Andrea Sabella	Ecologist	Bachelor of Environmental Science (Honours Class 1) (Biology), University of NSW, Sydney
Andrew Palmer-Brodie	Ecologist	Masters of Environmental Management , University of New England, Armidale Bachelor of Science, Australian National University, Canberra
Brian Towle	Senior Botanist	Bachelor of Environmental Science (First Class Honours), University of NSW, Sydney
Bruce Mullins	Senior Ecologist	Master of Science, University of Technology, Sydney. Bachelor of Science, University of Technology, Sydney
Chris McLean (Niche)	Ecologist	PhD Bachelor of Environmental Science (Honours)
Daniel McKenzie	Ecologist	Bachelor of Environmental Science and Management (Honours), University of Newcastle
Danielle Adams-Bennett	Ecologist	Bachelor of Animal Science (Wildlife Studies), University of Western Sydney
David Albrecht	Senior Botanist	Masters of Science (prelim.) in Taxonomic Botany, Melbourne University Diploma of Applied Science, Burnley Horticultural College, Melbourne University
Dr Enhua Lee	Senior Ecologist	PhD (Ecology and Wildlife Management), University of NSW, Sydney Bachelor of Advanced Science (Honours), University of NSW, Sydney
Dr Lachlan Copeland	Senior Botanist	PhD in plant systematics, University of New England Bachelor of Natural Resources (Hons), University of New England, Armidale
Dr Peter Hancock	Senior Aquatic Ecologist	PhD, Hyporheic Ecology - University of New England Bachelor of Natural Resources (Freshwater Ecology), University of New England, Armidale
Dr Rod Kavanagh (Niche)	Principal Research Ecologist	PhD Master of Science Graduate Diploma Natural Resources Dip Applied Science (Agriculture)

Field staff	Specialisation	Qualifications
Dr Rodney Armistead	Senior Ecologist	PhD in Conservation Biology, Murdoch University, Murdoch WA Bachelor of Advanced Science (Honours), Deakin University
Emily Southwell	Ecologist	Student of Masters of Integrated Water Management, International Water Centre (Universtiy of Queensland, Griffith University, Monash University & University of Western Australia) Bachelor of Natural Resources (Honours), University of New England, Armidale
Jack Talbert	Ecologist	Bachelor of Environmental Science (Land Resources) University of Wollongong
Kurtis Lindsay	Ecologist	Bachelor of Science (Biodiversity Conservation) (Honours Class 1) in Biological Science , Macquarie University, Sydney
Lucas McKinnon	Senior Ecologist	Student of Graduate Diploma in Ornithology, Charles Sturt University Bachelor of Environmental Science (Honours), University of Wollongong
Luke Geelan	Ecologist	Bachelor of Environmental Management (Honours), University of Adelaide, Adelaide
Martin Sullivan	Senior Botanist	Bachelor of Science (Biodiversity and Conservation), Macquarie University, Sydney Accredited BioBanking Assessor under the TSC Act
Matthew Dowle	Senior Ecologist	PhD (Biological Sciences and Wildlife Management), Macquarie University, Sydney Bachelor of Advanced Science (Honours), University of NSW, Sydney
Matthew Stanton (Niche)	Research Ecologist	Masters of Science (Zoology) Bachelor of Applied Science (Coastal Management)
Niels Rueegger	Ecologist	Bachelor of Environmental Science (Honours) Southern Cross University
Peter Knock	Senior Ecologist	Bachelor of Applied Science, University of Canberra Associate Diploma of Environmental Control, Mitchell College of Advanced Education
Prudence Coffey	Ecologist	Bachelor of Environmental Science (Terrestrial Ecology and Marine Management), University of New England, Armidale

Field staff	Specialisation	Qualifications
Rebecca McCue	Botanist	Bachelor of Arts (English Major) University of New England, Armidale Environmental Science (Biodiversity Conservation) University of New England, Armidale
Robert Brown-Cooper	Senior Ecologist	Bachelor of Science (Biology), Edith Cowan University, Mt Lawley WA
Rochelle Basham	Ecologist	Bachelor of Science (Honours) (University Medal in Biological Ecology), University of New South Wales, Sydney
Ross Wellington	Senior Ecologist	Bachelor of Arts (Biological Sciences), Macquarie University, Sydney
Sarah Dalgleish	Ecologist	Bachelor of Science (Environmental Management) Honours, Edith Cowan University, Mt Lawley WA
Will Introna	Senior Botanist Senior Ecologist	Master of Science, University of Technology, Sydney. Bachelor of Science (Environmental Biology), University of Technology Bachelor of Arts (Languages) (Honours), University of Sydney.

A3: Regional vegetation communities (RVCs) in the study area and the minimum number of plots required under the BioBanking methodology

RVC classes description	Biometric vegetation type (BVT) description	Plant community type (PCT) description	TSC Act*	EPBC Act*	Area (ha)	# biometric plots completed
Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South (RVC 96)	Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion (NA197)	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion (PCT 399)	~	~	1,093.46	20
		Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region (PCT 401)	~	~	7,580.41	34
Box - gum grassy woodlands, Brigalow Belt South and Nandewar (RVC 17)	Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (NA141)	Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (PCT 202)	EEC	~	589.82	16
Brigalow - Belah woodland on alluvial clay soil, mainly Brigalow Belt South (RVC 79)	Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion (NA117)	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion (PCT 35)	EEC	EEC	6,695.19	23
Broombush shrubland of the sand plains of the Pilliga region, Brigalow Belt South (RVC 31)	Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (NA121)	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion (PCT 141)	~	~	1,034.76	4
		Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion (PCT 425)	~	~	366.69	2
Carbeen woodland on alluvial soils, Darling Riverine Plains and Brigalow Belt South (RVC 85)	Carbeen woodland on alluvial soils (NA126)	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion (PCT 428)	EEC	~	15.03	2
Coolibah - Poplar Box - Belah woodlands on floodplains, mainly Darling Riverine Plains and Brigalow Belt South (RVC 76)	Belah woodland on alluvial plains in central-north NSW (NA102)	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions (PCT 55)	~	~	678.95	8
Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South (RVC 56)	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion (NA124)	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion (PCT 379)	~	~	103.56	0
		Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests (PCT 404)	~	~	9,982.48	34
		White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions (PCT 405)	~	~	6,650.54	17
		White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests (PCT 406)	~	~	3,232.39	8
		Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region (PCT 408)	~	~	3,188.25	9
		White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests (PCT 40X)	~	~	7,772.16	24
Ironbark – White Cypress Pine – Bulloak shrubby woodlands mainly of the Pilliga outwash area, Brigalow Belt South (RVC 33)	White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion (NA227)	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 BBS Bioregion (PCT 398)	~	~	23,975.35	60

RVC classes description	Biometric vegetation type (BVT) description	Plant community type (PCT) description	TSC Act*	EPBC Act*	Area (ha)	# biometric plots completed
	Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland on Jurassic Sandstone of outwash plains (NA160)	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion (PCT 402)	~	~	358.20	2
Pilliga Box - Poplar Box - White Cypress Pine shrub/grass woodland on sandy loams, Darling Riverine Plains and Brigalow Belt South (RVC 32)	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (NA179)	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion (PCT 88)	~	~	5,946.61	35
		Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion (PCT 397)	~	~	762.80	11
River Red Gum riverine woodlands and forests, Darling Riverine Plains, Brigalow Belt South and Nandewar (RVC 73)	River Red Gum riverine woodlands and forests in the Nandewar and Brigalow Belt South Bioregions (NA193)	River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions (PCT 78)	~	~	10.49	6
Shrubby woodlands or mallee woodlands on stoney soils, Brigalow Belt South and Nandewar (RVC 58)	Green Mallee scrub on sandstone rises in the Brigalow Belt South Bioregion (NA143)	Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion (PCT 256)	~	~	20.33	1
Weeping Myall open woodland, Darling Riverine Plains, Brigalow Belt South and Nandewar (RVC 75)	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions (NA219)	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions (PCT 27)	EEC	EEC	209.26	0
White Box - pine - Silver-leaved Ironbark shrubby open forests, Brigalow Belt South and Nandewar (RVC 44)	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (NA179)	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion (PCT 418)	~	~	131.59	6
Other (non-vegetation)		Includes cleared, creek bed, dams and improved pasture	~	~	14,678.37	5
Total					**95,076.69**	**327**

Not all Biometric Vegetation Types or Plant Community Types could be surveyed as part of the field surveys, due to their location.

* Not all components of the Plant Community Type may meet the relevant listing criteria under the TSC or EPBC Act. Refer to the technical report for accurate descriptions of endangered ecological communities (EECs).

A4: Survey timing for additional ecological assessments

#	Author	Report Name	Survey Type	2005	2006			2009			2010		2011				2012									2013									2014
				October	May	October	November	July	August	September	October	November	January	February	April	October	February	March	April	May	June	July	September	October	November	January	March	April	May	June	July	August	September	October	March
1	Kendall & Kendall Ecological Consultants	Fauna Study PEL 238 Coal Seam Gas	Fauna																																
2	Kendall & Kendall Ecological Consultants	Fauna Study Proposed Water Management Facility at Bibblewindi PEL 283 Coal Seam Gas	Fauna																																
3	Kendall & Kendall Ecological Consultants	Proposed Gas Pipeline, PEL 238 Coal Seam Gas Project. Fauna Assessment	Fauna																																
4, 5	Kendall & Kendall Ecological Consultants	Fauna Impact Assessment for Proposed Seismic Surveys - PEL 238 Coal Seam Gas Project PEL 238 Coal Sea Gas Project. Proposed Drilling of Two Exploratory Core Holes. Dewhurst 20 & 21. Fauna Assessment	Fauna																																
6	Idyll Spaces Environmental Consultants	PEL 238 Coal Seam Gas Flora Survey	Flora																																
7	Idyll Spaces Environmental Consultants	Flora Survey for propsed evaporation pond, PEL 238 Coal Seam Gas Project	Flora																																
8	Idyll Spaces Environmental Consultants	Flora Survey for proposed gas pipeline, PEL 238 Coal Seam Gas project	Flora																																
9, 10	Idyll Spaces Environmental Consultants	Flora assessment of proposed seismic surveys EC09 & EB09 Flora assessment : proposed drilling of two exploratory core holes, Dewhurst 20 & 21	Flora																																
48	Alison Hunt & Associates	CNC Project management Eastern Star Gas Narrabri to Wellington Gas Pipeline. Draft Ecological Assessment	Flora & Fauna																																
11	Northern Inland Council for the Environment (NICE) and The Wilderness Society (TWS)	The Biodiversity values of Pilliga East Forest and the Threats Posed by Coal Seam Gas Mining 2011 - 2011	Flora & Fauna																																
12	RPS	Due Dilligence Ecological Appraisal for a Proposed CSG exploration site, 'Kiandool', Narrabri	Flora & Fauna																																
13	RPS	Ecological Assessment: Galathere 1 Core Hole - PEL 238, Gunnedah Basin, NSW	Flora & Fauna																																
14	RPS	Ecological Assessment: Leewood - Produced Water and Brine Management Project (Phase 1)	Fauna																																
14	RPS	Ecological Assessment: Leewood - Produced Water and Brine Management Project (Phase 1)	Flora																																
15	RPS	Preliminary Ecological Assessment: Dewhurst 20 and 21 - PEL 238, Narrabri	Flora & Fauna																																
16	RPS	Ecological Assessment: Dewhurst Northern Water and Gas Flow Lines - PEL 238 and PAL 2, Gunnedah Basin, NSW	Flora																																
16	RPS	Ecological Assessment: Dewhurst Northern Water and Gas Flow Lines - PEL 238 and PAL 2, Gunnedah Basin, NSW	Fauna																																

#	Author	Report Name	Survey Type	2005	2006			2009			2010		2011				2012									2013									2014
				October	May	October	November	July	August	September	October	November	January	February	April	October	February	March	April	May	June	July	September	October	November	January	March	April	May	June	July	August	September	October	March
17	RPS	Ecological Assessment: Bibblewindi 30 Core Hole, Narrabri	Habitat																																
17	RPS	Ecological Assessment: Bibblewindi 30 Core Hole, Narrabri	Flora																																
18	RPS	Ecological Assesment: Dewhurst 13 - 18 Gathering System, Narrabri	Flora																																
18	RPS	Ecological Assesment: Dewhurst 13 - 18 Gathering System, Narrabri	Habitat																																
19	RPS	Ecological Assessment: Dewhurst 22 - 25 - PEL 238, Narrabri	Flora																																
19	RPS	Ecological Assessment: Dewhurst 22 - 25 - PEL 238, Narrabri	Fauna																																
20, 21, 23	RPS	Ecological Assessment: Dewhurst 26 - 29 Pilot Wells - PEL 238, Narrabri Ecological Assessment: Dewhurst Southern Water and Gas Flow Lines - PEL 238 and PAL 2, Narrabri Preliminary Ecological Assessment: Dewhurst 21 - PEL 238, Narrabri	Flora & Fauna																																
22	RPS	Ecological Assessment: Narrabri West Core Hole - PEL238, Gunnedah Basin, NSW	Flora & Habitat																																
23	RPS	Preliminary Ecological Assessment: Dewhurst 21 - PEL 238, Narrabri	Flora & Habitat																																
32	ELA	Energy NSW Coal Seam Gas Exploration and Appraisal Program: Pre-clearing and clearing report	Fauna																																
33	ELA	Dewhurst Gas Exploration Pilot Expansion. Ecological Assessment for the expansion of operations at Dewhurst 13 - 18H and Dewhurst 26 - 31 pilots	Flora & Fauna																																

#	Author	Report Name		2005	2006			2009			2010		2011				2012									2013									2014
			Survey Type	October	May	October	November	July	August	September	October	November	January	February	April	October	February	March	April	May	June	July	September	October	November	January	March	April	May	June	July	August	September	October	March
47	ELA	ENSW Core hole and 4 Spot Pilot Environmental Assessment Ecological Impact Assessment for Bibblewindi 34 Core hole and Dewhurst 4-Spot Pilot (32, 33, 36 & 37)	Flora & Fauna																																

A5: Threatened fauna predicted and known habitat associations

Species name	Common name	Closed Forest	Water bodies	Grassland	Grassy Woodland	Heath	Heathy Woodland	Riparian Woodland	Shrub Grass Woodland	Shrubby Woodland
Aepyprymnus rufescens	Rufous Bettong									
Anseranas semipalmata	Magpie Goose									
*Anthochaera phrygia**	Regent Honeyeater									
Apus pacificus	Fork-tailed Swift									
Ardea modesta	Great Egret, White Egret									
Ardea ibis	Cattle Egret									
Ardeotis australis	Australian Bustard									
Aramus cyanopterus cyanopterus	Dusky Woodswallow									
Botaurus poiciloptilus	Australasian Bittern									
Burhinus grallarius	Bush Stone-curlew									
Calidris acuminata	Sharp-tailed Sandpiper									
Calyptorhynchus lathami	Glossy Black-Cockatoo									
*Cercartetus nanus**	Eastern Pygmy-possum									
Chalinolobus dwyeri	Large-eared Pied Bat									
Chalinolobus picatus	Little Pied Bat									
Chthonicola sagittata	Speckled Warbler									
Circus assimilis	Spotted Harrier									
Crinia sloanei	Sloane's Froglet									
Daphoenositta chrysoptera	Varied Sittella									
Dasyurus maculatus	Spotted-tailed Quoll									
Ephippiorhynchus asiaticus	Black-necked Stork									
Falco hypoleucos	Grey Falcon									
Falco subniger	Black Falcon									
Gallinago hardwickii	Latham's Snipe, Japanese Snipe									
Glossopsitta pusilla	Little Lorikeet									
Grantiella picta	Painted Honeyeater									

Species name	Common name	Closed Forest	Water bodies	Grassland	Grassy Woodland	Heath	Heathy Woodland	Riparian Woodland	Shrub Grass Woodland	Shrubby Woodland
Grus rubicunda	Brolga									
Hamirostra melanosternon	Black-breasted Buzzard									
Hieraaetus morphnoides	Little Eagle									
Hirundapus caudacutus	White-throated Needletail									
Hoplocephalus bitorquatus	Pale-headed Snake									
*Lathamus discolor**	Swift Parrot									
Lophoictinia isura	Square-tailed Kite									
Macropus dorsalis	Black-striped Wallaby									
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)									
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)									
Merops ornatus	Rainbow Bee-eater									
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat									
Myiagra cyanoleuca	Satin Flycatcher									
Neophema pulchella	Turquoise Parrot									
Ninox connivens	Barking Owl									
Nyctophilus corbeni (syn. *Nyctophilus timoriensis* (South-eastern form))	South-eastern Long eared Bat / Corben's Long-eared Bat									
Oxyura australis	Blue-billed Duck									
Pachycephala inornata	Gilbert's Whistler									
Petaurus norfolcensis	Squirrel Glider									
Petroica boodang	Scarlet Robin									
*Phascolarctos cinereus**	Koala									
Plegadis falcinellus	*Glossy Ibis*									
*Polytelis swainsonii**	Superb Parrot									
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)									
*Pseudomys pilligaensis**	Pilliga Mouse									
Rostratula australis (syn. *Rostratula benghalensis australis*)	Australian Painted Snipe									

Species name	Common name	Closed Forest	Water bodies	Grassland	Grassy Woodland	Heath	Heathy Woodland	Riparian Woodland	Shrub Grass Woodland	Shrubby Woodland
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat									
*Sminthopsis macroura**	Stripe-faced Dunnart									
Stagonopleura guttata	Diamond Firetail									
Stictonetta naevosa	Freckled Duck									
Tyto novaehollandiae	Masked Owl									
Vespadelus troughtoni	Eastern Cave Bat									

Green shading = known, pink shading = likely, orange shading = potential, * after scientific name indicates habitat associations determined by Plant Community Type

A6: Impacts: vegetation communities

Plant Community Type	Condition	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Estimated direct impact (ha)	Estimated indirect impact (ha)	Total in project area (ha)	Total in the study region (ha) by BVT (Oct 2008)	% directly impacted in the study area	% total impacted in the study area (direct and indirect)
55 - Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	Derived Native Grassland	NA102	NA102	1.7	0.0	320.0	7,734.9	0.53%	0.53%
55 - Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	Native Vegetation	NA102	NA102	3.9	0.8	358.9		1.09%	1.31%
35 - Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	Derived Native Grassland	NA117	NA117	37.2	0.0	4,227.2	8,704.2	0.88%	0.88%
35 - Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	**Native Vegetation**	**NA117**	**NA117**	**19.3**	**3.9**	**2,468.0**		**0.78%**	**0.94%**
141 - Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	Native Vegetation	NA121	NA121	19.5	4.0	1,034.8	14,014.5	1.88%	2.27%
425 - Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	Native Vegetation	NA121	NA363	8.4	1.7	366.7		2.29%	2.75%
379 - Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion	Native Vegetation	NA124	NA294	2.7	0.5	103.6	73,730.9	2.61%	3.09%
404 - Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	Native Vegetation	NA124	NA326	86.6	17.6	9,982.5		0.87%	1.04%
405 - White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	Native Vegetation	NA124	NA390	108.7	22.1	6,650.5		1.63%	1.97%
406 - White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests	Native Vegetation	NA124	NA389	69.0	14.0	3,232.4		2.13%	2.57%
408 - Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region	Derived Native Grassland	NA124	NA279	0.4	0.0	103.5		0.39%	0.39%
408 - Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region	Native Vegetation	NA124	NA279	33.3	6.8	3,084.8		1.08%	1.30%
40X - White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests	Derived Native Grassland	NA124	NA390	1.9	0.0	239.5		0.79%	0.79%
40X - White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests	Native Vegetation	NA124	NA390	138.4	26.4	7,532.6		1.84%	2.19%
428 - Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	**Native Vegetation**	**NA126**	**NA267**	**0.0**	**0.0**	**15.0**	133.3	**0.00%**	**0.00%**

Plant Community Type	Condition	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Estimated direct impact (ha)	Estimated indirect impact (ha)	Total in project area (ha)	Total in the study region (ha) by BVT (Oct 2008)	% directly impacted in the study area	% total impacted in the study area (direct and indirect)
202 - Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion	**Derived Native Grassland**	**NA141**	**NA141**	**0.0**	**0.0**	**1.4**	2,674.7	**0.00%**	**0.00%**
202 - Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion	**Native Vegetation**	**NA141**	**NA141**	**5.9**	**1.2**	**588.4**		**1.00%**	**1.21%**
256 - Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion	Native Vegetation	NA143	NA292	0.3	0.1	20.3	1,161.0	1.48%	1.97%
402 - Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	Native Vegetation	NA160	NA307	1.6	0.3	175.1	21,397.7	0.91%	1.08%
402 - Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	Derived Native Grassland	NA160	NA307	1.6	0.0	183.1		0.87%	0.87%
88 - Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	Derived Native Grassland	NA179	NA179	8.8	0.0	1,518.5	37,592.8	0.58%	0.58%
88 - Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	Native Vegetation	NA179	NA179	40.8	8.2	4,428.1		0.92%	1.11%
397 - Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	Derived Native Grassland	NA179	NA324	1.3	0.0	445.9		0.29%	0.29%
397 - Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	Native Vegetation	NA179	NA324	1.0	0.2	317.0		0.32%	0.38%
418 - White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	Native Vegetation	NA179	NA409	0.2	0.1	62.3		0.32%	0.43%
418 - White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	Derived Native Grassland	NA179	NA409	0.3	0.0	69.3		0.43%	0.43%
78 - River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	Native Vegetation	NA193	NA193	0.0	0.0	10.5	8,475.2	0.00%	0.00%
399 - Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	Derived Native Grassland	NA197	NA255	0.2	0.0	47.1	14,472.9	0.42%	0.42%
399 - Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	Native Vegetation	NA197	NA255	3.4	0.7	1,046.4		0.32%	0.39%
401 - Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	Derived Native Grassland	NA197	NA338	18.1	0.0	1,641.2		1.10%	1.10%
401 - Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	Native Vegetation	NA197	NA338	46.4	9.2	5,939.2		0.78%	0.94%

Plant Community Type	Condition	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Estimated direct impact (ha)	Estimated indirect impact (ha)	Total in project area (ha)	Total in the study region (ha) by BVT (Oct 2008)	% directly impacted in the study area	% total impacted in the study area (direct and indirect)
27 - Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	**Native Vegetation**	**NA219**	**NA219**	**0.1**	**0.0**	**36.0**	126.1	**0.28%**	**0.28%**
27 - Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	Derived Native Grassland	NA219	NA219	0.5	0.0	173.3		0.29%	0.29%
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 BBS Bioregion	Derived Native Grassland	NA227	NA314	3.9	0.0	494.9	106,986.3	0.79%	0.79%
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 BBS Bioregion	Native Vegetation	NA227	NA314	323.4	63.4	23,480.4		1.38%	1.65%
			Total	**988.8**	**181.1**	**80,398.3**	**297,204.3**	**1.23%**	**1.46%**

A7: Direct impact: fauna habitat

Scientific Name	Common Name	Habitat in study area			Habitat in study region			Direct impact (ha)			Percentage directly impacted in the study area		
		Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
Parrots													
Calyptorhynchus lathami	Glossy Black-Cockatoo	66,005.45	66,705.00	0	26,5710.7	285,998.3	0	854.20	861.80	0	1.29%	1.29%	N/A
Glossopsitta pusilla	Little Lorikeet	66,804.97	66,705.01	0	29,2430.9	285,998.3	0	861.80	861.80	0	1.29%	1.29%	N/A
Neophema pulchella	Turquoise Parrot	77,671.41	66,705.00	0	340,751.4	285,998.3	0	965.60	861.80	0	1.24%	1.29%	N/A
Parrots - winter migratory													
Lathamus discolor	Swift Parrot	57,579.21	0	0	246,370.1	0	0	796.80	0	0	1.38%	N/A	N/A
Polytelis swainsonii	Superb Parrot	35,573.88	0	0	195,490.2	0	0	416.80	0	0	1.17%	N/A	N/A
Owls													
Ninox connivens	Barking Owl	80,498.28	69,531.87	0	357,190.6	302,437.4	0	988.80	885.00	0	1.23%	1.27%	N/A
Tyto novaehollandiae	Masked Owl	80,498.28	69,531.87	0	357,190.6	302,437.4	0	988.80	885.00	0	1.23%	1.27%	N/A
Birds of prey													
Circus assimilis	Spotted Harrier	45,663.27	36,098.31	0	251,845.1	211,106.4	0	498.70	422.80	0	1.09%	1.17%	N/A
Falco hypoleucos	Grey Falcon	16,576.04	0	0	75,759.02	0	0	125.70	0	0	0.76%	N/A	N/A
Falco subniger	Black Falcon	77,571.44	66,705.00	0	334,318.9	285,998.3	0	965.60	861.80	0	1.24%	1.29%	N/A
Hamirostra melanosternon	Black-breasted Buzzard	80,498.28	7,011.08	0	357,190.6	35,020.4	0	988.80	49.80	0	1.23%	0.71%	N/A
Hieraaetus morphnoides	Little Eagle	76,269.96	66,705.00	0	326,737.0	285,998.3	0	937.70	861.80	0	1.23%	1.29%	N/A
Lophoictinia isura	Square-tailed Kite	76,269.96	7,011.08	0	326,737.0	35,020.4	0	937.70	49.80	0	1.23%	0.71%	N/A
Woodland birds - large ground foraging													
Ardeotis australis	Australian Bustard	9,564.96	0	0	40,738.7	0	0	75.90	0	0	0.79%	N/A	N/A
Burhinus grallarius	Bush Stone-curlew	45,563.30	36,098.31	0	245,412.6	211,106.4	0	498.70	422.80	0	1.09%	1.17%	N/A
Woodland birds - ground and midstorey foraging (passerines)													
Artamus cyanopterus cyanopterus	Dusky Woodswallow	77,671.41	68,106.45	0	340,751.4	300,012.8	0	965.60	889.70	0	1.24%	1.31%	N/A
Chthonicola sagittata	Speckled Warbler	45,663.27	36,098.31	0	251,845.1	211,106.4	0	498.70	422.80	0	1.09%	1.17%	N/A
Daphoenositta chrysoptera	Varied Sittella	69,531.87	69,531.87	0	302,437.4	302,437.4	0	885.00	885.00	0	1.27%	1.27%	N/A
Melanodryas cucullata	Hooded Robin	77,671.41	68,106.45	0	340,751.4	300,012.8	0	965.60	889.70	0	1.24%	1.31%	N/A
Pachycephala inornata	Gilbert's Whistler	69,631.87	69,531.87	0	308,870.0	302,437.4	0	885.00	885.00	0	1.27%	1.27%	N/A
Petroica boodang	Scarlet Robin	76,270.0	66,705.00	0	326,737.0	285,998.3	0	937.70	861.80	0	1.23%	1.29%	N/A
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	80,498.28	69,531.87	0	357,190.6	302,437.4	0	988.80	885.00	0	1.23%	1.27%	N/A
Stagonopleura guttata	Diamond Firetail	45,663.27	36,098.31	0	251,845.1	211,106.4	0	498.70	422.80	0	1.09%	1.17%	N/A

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Habitat in study area			Habitat in study region			Direct impact (ha)			Percentage directly impacted in the study area		
Woodland birds - canopy foraging (excluding parrots)													
Anthochaera phrygia	Regent Honeyeater	57,579.21	0	0	246,370.1	0	0	796.80	0	0	1.38%	N/A	N/A
Grantiella picta	Painted Honeyeater	69,631.84	69,531.87	0	308,870.0	302,437.4	0	885.00	885.00	0	1.27%	1.27%	N/A
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	66,804.97	66,705.00	0	292,430.9	285,998.3	0	861.80	861.80	0	1.29%	1.29%	N/A
Wetland or aquatic birds													
Anseranas semipalmata	Magpie Goose	99.97	99.97	0	6,432.5	6,432.5	0	0	0	0	0%	0%	N/A
Botaurus poiciloptilus	Australasian Bittern	99.97	0	0	6,432.5	0	0	0	0	0	0%	0%	N/A
Ephippiorhynchus asiaticus	Black-necked Stork	99.97	99.97	0	6,432.5	6,432.5	0	0	0	0	0%	0%	N/A
Grus rubicunda	Brolga	9,564.96	0	0	40,738.67	0	0	75.90	0	0	0.79%	N/A	N/A
Oxyura australis	Blue-billed Duck	99.97	99.9	0	6,432.53	6,432.53	0	0	0	0	0%	0%	N/A
Rostratula australis	Australian Painted Snipe	99.97	99.97	0	6,432.53	6,432.53	0	0	0	0	0%	0%	N/A
Stictonetta naevosa	Freckled Duck	99.97	99.97	0	6,432.53	6,432.53	0	0	0	0	0%	0%	N/A
Mammals – unique habitat requirements													
Aepyprymnus rufescens	Rufous Bettong	45,563.30	36,098.31	0	245,412.6	211,106.4	0	498.70	422.80	0	1.09%	1.17%	N/A
Dasyurus maculatus	Spotted-tailed Quoll	80,498.28	69,531.87	0	357,190.6	302,437.4	0	988.80	885.00	0	1.23%	1.27%	N/A
Macropus dorsalis	Black-striped Wallaby	80,498.28	80,498.28	0	357,190.6	357,190.6	0	988.80	988.80	0	1.23%	1.23%	N/A
Pseudomys pilligaensis	Pilliga Mouse	14,609.0 (secondary)	8,595.4 (primary)	68,050.12	73,730.89	73,730.89	279,477.7	181.51 (secondary)	135.04 (primary)	572.76	1.24% (secondary)	1.57% (primary)	0.84%
Phascolarctos cinereus	Koala	32,995.62	32,995.62	80,398.31	100,080.9	100,080.9	331,510.0	449.80	449.80	988.80	1.36%	1.36%	1.23%
Sminthopsis macroura	Stripe-faced Dunnart	44,330.70	44,330.70	0	138,750.0	138,750.0	0	565.80	565.80	0	1.28%	1.28%	N/A
Arboreal hollow-dependent fauna													
Cercartetus nanus	Eastern Pygmy-possum	56,666.19	56,666.19	0	228,597.8	228,597.8	0	774.80	774.80	0	1.37%	1.37%	N/A
Petaurus norfolcensis	Squirrel Glider	66,705.00	66,705.00	0	285,998.3	285,998.3	0	861.80	861.80	0	1.29%	1.29%	N/A
Predominantly tree-roosting bats													
Chalinolobus picatus	Little Pied Bat	70,933.32	69,531.87	0	316,451.9	302,437.4	0	912.90	885.00	0	1.29%	1.27%	N/A
Nyctophilus corbeni (syn. Nyctophilus timoriensis (South-eastern form))	Greater Long-eared Bat	69,531.87	69,531.87	0	302,437.4	302,437.4	0	885.00	885.00	0	1.27%	1.27%	N/A
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	80,398.31	69,531.87	0	350,758.0	302,437.4	0	988.80	885.00	0	1.23%	1.27%	N/A
Predominantly cave-roosting bats													
Chalinolobus dwyeri	Large-eared Pied Bat	69,531.87	0	0	302,437.4	0	0	885.00	0	0	1.27%	N/A	N/A
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	80,498.28	0	0	357,190.6	0	0	988.80	0	0	1.23%	N/A	N/A

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Habitat in study area			Habitat in study region			Direct impact (ha)			Percentage directly impacted in the study area		
Vespadelus troughtoni	Eastern Cave Bat	69,531.87	0	0	302,437.4	0	0	885.00	0	0	1.27%	N/A	N/A
Reptiles													
Hoplocephalus bitorquatus	Pale-headed Snake	69,531.87	69,531.87	0	302,437.4	302,437.4	0	885.00	885.00	0	1.27%	1.27%	N/A
Migratory birds													
Apus pacificus	Fork-tailed Swift	80,498.28	0	0	357,190.6	0	0	988.80	0	0	1.23%	N/A	N/A
Ardea ibis	Cattle Egret	9,564.96	0	0	40,738.67	0	0	75.90	0	0	0.79%	N/A	N/A
Ardea modesta,	Great Egret	9,564.96	0	0	40,738.67	0	0	75.90	0	0	0.79%	N/A	N/A
Calidris acuminata	Sharp-tailed Sandpiper	99.97	0	0	6,432.53	0	0	0	0	0	0%	N/A	N/A
Gallinago hardwickii	Latham's Snipe	99.97	99.97	0	6,432.53	6,432.53	0	0	0	0	0%	0%	N/A
Hirundapus caudacutus	White-throated Needletail	80,498.28	0	69,531.87	357,190.6	0	302,437.4	988.80	0	885.00	1.23%	N/A	1.27%
Merops ornatus	Rainbow Bee-eater	77,671.41	66,804.97	0	340,751.4	292,430.8	0	965.60	861.80	0	1.24%	1.29%	N/A
Myiagra cyanoleuca	Satin flycatcher	66,804.97	66,705.00	0	292,430.8	287,870.05	0	861.80	861.80	0	1.29%	1.29%	N/A
Plegadis falcinellus	Glossy Ibis	99.97	99.97	0	6,432.53	6,432.53	0	0	0	0	0%	0%	N/A

* Other: Pilliga Mouse/Koala – dispersal habitat; White-throated Needletail: roosting. For the majority of species, roosting habitat is contained within breeding and foraging habitat.

Note that Pilliga Mouse habitat modelling was used to calculate the values of Pilliga Mouse primary and secondary habitat in the study area.

A8: Direct impact: hollow-bearing trees

Plant Community Type	Direct Impacts Hollow size class <200	 >200 < 300	 >300	% loss within the study area Hollow size class <200	 >200 < 300	 >300
Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	0.24	0	0.04	0.28%	0%	0.28%
Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	46.32	0	8.04	0.78%	0%	0.78%
Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	9. 75	0	0	1.09%	0%	0%
River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	0	0	0	0%	0%	0%
Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	521.33	62.77	47.08	0.92%	0.92%	0.92%
Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	0	0	0	0%	0%	0%
Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion	95.88	14.75	3.93	1.00%	1.00%	1.00%
Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion	0	0	0	0%	0%	0%
Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS	28.13	5.63	3.83	2.61%	2.61%	2.61%
Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	13.64	0	0	0.32%	0%	0%
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 BBS Bioregion	1,509.20	107.80	53.90	1.38%	1.38%	1.38%
Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	69.70	13.22	1.89	0.32%	0.32%	0.32%
Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	874.94	128.00	128.00	0.78%	0.78%	0.78%
Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	8.00	0	0	0.91%	0%	0%
Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	942.41	305.65	229.24	0.87%	0.87%	0.87%
White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	1,214.88	63.94	255.76	1.63%	1.63%	1.63%
White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests	517.50	0	172.50	2.13%	0%	2.13%
Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region	518.00	185.00	37.00	1.08%	1.08%	1.08%
White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	0.57	0	0	0.32%	0%	0%
Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	42.00	0	0	2.29%	0%	0%
Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	0	0	0	0%	0%	0%
White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests	1,441.67	288.33	173.00	1.84%	1.84%	1.84%
	7,854.20	**1,175.1**	**1,113.8**	**1.19%**	**1.08%**	**1.23%**

A9: Indirect and total impact: fauna habitat

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Indirect impact (ha)			Total impact (direct and indirect) (ha)			Percentage indirectly impacted in the study area			Percentage total (direct and indirect) impact in the study area		
Parrots													
Calyptorhynchus lathami	Glossy Black-Cockatoo	169.18	170.71	0	1,023.38	1,032.51	0	0.26%	0.26%	N/A	1.55%	1.55%	N/A
Glossopsitta pusilla	Little Lorikeet	170.71	170.71	0	1,032.51	1,032.51	0	0.26%	0.26%	N/A	1.55%	1.55%	N/A
Neophema pulchella	Turquoise Parrot	176.41	170.71	0	1,142.01	1,032.51	0	0.23%	0.26%	N/A	1.47%	1.55%	N/A
Parrots - winter migratory													
Lathamus discolor	Swift Parrot	157.48	0	0	954.28	0	0	0.27%	N/A	N/A	1.66%	N/A	N/A
Polytelis swainsonii	Superb Parrot	82.02	0	0	498.82	0	0	0.23%	N/A	N/A	1.40%	N/A	N/A
Owls													
Ninox connivens	Barking Owl	181.11	175.41	0	1,169.91	1,060.41	0	0.22%	0.25%	N/A	1.45%	1.53%	N/A
Tyto novaehollandiae	Masked Owl	181.11	175.41	0	1,169.91	1,060.41	0	0.22%	0.25%	N/A	1.45%	1.53%	N/A
Birds of prey													
Circus assimilis	Spotted Harrier	83.25	83.25	0	581.95	506.05	0	0.18%	0.23%	N/A	1.27%	1.40%	N/A
Falco hypoleucos	Grey Falcon	9.88	0	0	135.58	0	0	0.06%	N/A	N/A	0.82%	N/A	N/A
Falco subniger	Black Falcon	176.41	170.71	0	1,142.01	1,032.51	0	0.23%	0.26%	N/A	1.47%	1.55%	N/A
Hamirostra melanosternon	Black-breasted Buzzard	181.11	9.88	0	1,169.91	59.68	0	0.22%	0.14%	N/A	1.45%	0.85%	N/A
Hieraaetus morphnoides	Little Eagle	170.71	170.71	0	1,108.41	1,032.51	0	0.22%	0.26%	N/A	1.45%	1.55%	N/A
Lophoictinia isura	Square-tailed Kite	170.71	9.88	0	1,108.41	59.68	0	0.22%	0.14%	N/A	1.45%	0.85%	N/A
Woodland birds - large ground foraging													
Ardeotis australis	Australian Bustard	0	0	0	75.90	0	0	0%	N/A	N/A	0.79%	N/A	N/A
Burhinus grallarius	Bush Stone-curlew	83.25	83.25	0	581.95	506.05	0	0.18%	0.23%	N/A	1.27%	1.40%	N/A
Woodland birds - ground and midstorey foraging (passerines)													
Artamus cyanopterus cyanopterus	Dusky Woodswallow	176.41	176.41	0	1,142.01	1,066.11	0	0.23%	0.26%	N/A	1.47%	1.57%	N/A
Chthonicola sagittata	Speckled Warbler	83.25	83.25	0	581.95	506.05	0	0.18%	0.23%	N/A	1.27%	1.40%	N/A
Daphoenositta chrysoptera	Varied Sittella	175.41	175.41	0	1,060.41	1,060.41	0	0.25%	0.25%	N/A	1.53%	1.53%	N/A
Melanodryas cucullata	Hooded Robin	176.41	176.41	0	1,142.01	1,066.11	0	0.23%	0.26%	N/A	1.47%	1.57%	N/A
Pachycephala inornata	Gilbert's Whistler	175.41	175.41	0	1,060.41	1,060.41	0	0.25%	0.25%	N/A	1.52%	1.53%	N/A
Petroica boodang	Scarlet Robin	170.71	170.71	0	1,108.41	1,032.51	0	0.22%	0.26%	N/A	1.45%	1.55%	N/A
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	181.11	175.41	0	1,169.91	1,060.41	0	0.22%	0.25%	N/A	1.45%	1.53%	N/A

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Indirect impact (ha)			Total impact (direct and indirect) (ha)			Percentage indirectly impacted in the study area			Percentage total (direct and indirect) impact in the study area		
Stagonopleura guttata	Diamond Firetail	83.25	83.25	0	581.95	506.05	0	0.18%	0.23%	N/A	1.27%	1.40%	N/A
Woodland birds - canopy foraging (excluding parrots)													
Anthochaera phrygia	Regent Honeyeater	157.48	0	0	954.28	0	0	0.27%	N/A	N/A	1.66%	N/A	N/A
Grantiella picta	Painted Honeyeater	175.41	175.41	0	1,060.41	1,060.41	0	0.25%	0.25%	N/A	1.52%	1.53%	N/A
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	170.71	170.71	0	1,032.51	1,032.51	0	0.26%	0.26%	N/A	1.55%	1.55%	N/A
Wetland or aquatic birds													
Anseranas semipalmata	Magpie Goose	0	0	0	0	0	0	0%	0%	N/A	0%	0%	N/A
Botaurus poiciloptilus	Australasian Bittern	0	0	0	0	0	0	0%	N/A	N/A	0%	N/A	N/A
Ephippiorhynchus asiaticus	Black-necked Stork	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A
Grus rubicunda	Brolga	0	0	0	75.90	0	0	0%	N/A	N/A	0.79%	N/A	N/A
Oxyura australis	Blue-billed Duck	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A
Rostratula australis	Australian Painted Snipe	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A
Stictonetta naevosa	Freckled Duck	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A
Mammals – unique habitat requirements													
Aepyprymnus rufescens	Rufous Bettong	83.25	83.25	0	581.95	506.05	0	0.18%	0.23%	N/A	1.28%	1.40%	N/A
Dasyurus maculatus	Spotted-tailed Quoll	181.11	175.41	0	1,169.91	1,060.41	0	0.22%	0.25%	N/A	1.45%	1.53%	N/A
Macropus dorsalis	Black-striped Wallaby	181.11	181.11	0	1,169.91	1,169.91	0	0.22%	0.22%	N/A	1.45%	1.45%	N/A
Pseudomys pilligaensis	Pilliga Mouse	33.24 (secondary)	24.73 (primary)	104.9	214.75 (secondary)	159.77 (primary)	677.66	0.23% (secondary)	0.29% (primary)	0.15%	1.47%	1.86%	1.00%
Phascolarctos cinereus	Koala	89.36	89.36	181.11	539.16	539.16	1169.91	0.27%	0.27%	0.23%	1.63%	1.63%	1.46%
Sminthopsis macroura	Stripe-faced Dunnart	97.76	97.76	0	663.56	663.56	0	0.22%	0.22%	N/A	1.50%	1.50%	N/A
Arboreal hollow-dependent fauna													
Cercartetus nanus	Eastern Pygmy-possum	153.01	153.01	0	927.81	927.81	0	0.27%	0.27%	N/A	1.63%	1.64%	N/A
Petaurus norfolcensis	Squirrel Glider	170.71	170.71	0	1,032.51	1,032.51	0	0.26%	0.26%	N/A	1.55%	1.55%	N/A
Predominantly tree-roosting bats													
Chalinolobus picatus	Little Pied Bat	181.11	175.41	0	1,094.01	1,060.41	0	0.26%	0.25%	N/A	1.54%	1.53%	N/A
Nyctophilus corbeni (syn. *Nyctophilus timoriensis* (South-eastern form))	Greater Long-eared Bat	175.41	175.41	0	1,060.41	1,060.41	0	0.25%	0.25%	N/A	1.53%	1.53%	N/A
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	181.11	175.41	0	1,169.91	1,060.41	0	0.23%	0.25%	N/A	1.46%	1.53%	N/A
Predominantly cave-roosting bats													
Chalinolobus dwyeri	Large-eared Pied Bat	175.41	0	0	1,060.41	0	0	0.25%	N/A	N/A	1.53%	N/A	N/A

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Indirect impact (ha)			Total impact (direct and indirect) (ha)			Percentage indirectly impacted in the study area			Percentage total (direct and indirect) impact in the study area		
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	181.11	0	0	1,169.91	0	0	0.22%	N/A	N/A	1.45%	N/A	N/A
Vespadelus troughtoni	Eastern Cave Bat	175.41	0	0	1,060.41	0	0	0.25%	N/A	N/A	1.53%	N/A	N/A
Reptiles													
Hoplocephalus bitorquatus	Pale-headed Snake	175.41	175.41	0	1,060.41	1,060.41	0	0.25%	0.25%	N/A	1.53%	1.53%	N/A
Migratory birds													
Apus pacificus	Fork-tailed Swift	181.11	0	0	1,169.91	0	0	0.22%	N/A	N/A	1.45%	N/A	N/A
Ardea ibis	Cattle Egret	0	0	0	75.90	0	0	0%	N/A	N/A	0.79%	N/A	N/A
Ardea modesta,	Great Egret	0	0	0	75.90	0	0	0%	N/A	N/A	0.79%	N/A	N/A
Calidris acuminata	Sharp-tailed Sandpiper	0.0	0	0	0.0	0	0	0%	N/A	N/A	0%	N/A	N/A
Gallinago hardwickii	Latham's Snipe	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A
Hirundapus caudacutus	White-throated Needletail	181.11	0	175.41	1,169.91	0	1,060.41	0.22%	N/A	0.25%	1.45%	N/A	1.53%
Merops ornatus	Rainbow Bee-eater	176.41	170.71	0	1,142.01	1,032.51	0	0.23%	0.26%	N/A	1.47%	1.55%	N/A
Myiagra cyanoleuca	Satin flycatcher	170.71	170.71	0	1,032.51	1,032.51	0	0.26%	0.26%	N/A	1.55%	1.55%	N/A
Plegadis falcinellus	Glossy Ibis	0.0	0	0	0.0	0	0	0%	0%	N/A	0%	0%	N/A

* Other: Pilliga Mouse/Koala – dispersal habitat; White-throated Needletail: roosting. For the majority of species, roosting habitat is contained within breeding and foraging habitat.

Note that Pilliga Mouse habitat modelling was used to calculate the values of Pilliga Mouse primary and secondary habitat in the study area.

A10: Cumulative impact: vegetation

Biometric vegetation type	Existing or approved impact (ha)	Narrabri Gas Project impact (direct and indirect) (ha)	Cumulative impact (ha)	Impact in the study region (%)
Belah woodland (NA 102)	0	4.70	4.70	0.06%
Brigalow – Belah woodland (NA 117)	10.22	23.2	33.42	0.38%
Broombush shrubland (NA 121)	0	33.6	33.60	0.24%
Brown Bloodwood - cypress - ironbark heathy woodland (NA 124)	196.05	526.06	722.11	1.96%
Carbeen woodland (NA 126)	0	0	0	0.00%
Derived native grassland	177.5	75.90	253.40	0.77%
Fuzzy Box (NA 141)	1.78	7.13	8.91	0.33%
Green Mallee scrub (NA 143)	0	0.40	0.40	0.03%
Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland (NA 160)	0	1.90	1.90	0.01%
Native Millet - Cup grasslands (NA 214)	1.94	0	1.94	0.17%
Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland (NA 179)	11.77	50.49	62.26	0.17%
Plains Grass grassland (NA 181)	0.38	0	0.38	0.57%
River Red Gum riverine woodland and forests (NA 193)	0	0	0	0.00%
Rough-barked Apple riparian forb/grass open forest (NA 197)	12.41	59.68	72.09	0.50%
Semi permanent open freshwater wetlands (NA 200)	0.25	0	0.25	0.01%
Weeping Myall open woodland (NA 219)	0	0.10	0.10	0.08%
White Cypress Pine - Bulloak - ironbark woodland (NA 227)	119.3	386.75	506.05	0.47%
Total	**531.63**	**1,169.91**	**1,701.51**	**0.57%**

A11: Cumulative impact: fauna habitat

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Cumulative impact (ha)			Percentage cumulatively impacted in the study region		
Parrots							
Calyptorhynchus lathami	Glossy Black-Cockatoo	1,363.16	1,373..82	0	0.51%	0.48%	N/A
Glossopsitta pusilla	Little Lorikeet	1,374.07	1,373.82	0	0.47%	0.48%	N/A
Neophema pulchella	Turquoise Parrot	1,663.39	1,373.82	0	0.49%	0.48%	N/A
Parrots – winter migratory							
Lathamus discolor	Swift Parrot	1,196.04	0	0	0.49%	N/A	N/A
Polytelis swainsonii	Superb Parrot	642.55	0	0	0.33%	N/A	N/A
Owls							
Ninox connivens	Barking Owl	1,701.51	1,411.94	0	0.48%	0.47%	N/A
Tyto novaehollandiae	Masked Owl	1,701.51	1,411.94	0	0.48%	0.47%	N/A
Birds of prey							
Circus assimilis	Spotted Harrier	907.28	651.31	0	0.36%	0.31%	N/A
Falco hypoleucos	Grey Falcon	328.06	0	0	0.43%	N/A	N/A
Falco subniger	Black Falcon	1,663.14	1,373.82	0	0.50%	0.48%	N/A
Hamirostra melanosternon	Black-breasted Buzzard	1,701.51	72.09	0	0.48%	0.21%	N/A
Hieraaetus morphnoides	Little Eagle	1,629.79	1,373.82	0	0.50%	0.48%	N/A
Lophoictinia isura	Square-tailed Kite	1,629.79	72.09	0	0.50%	0.21%	N/A
Woodland birds - large ground foraging							
Ardeotis australis	Australian Bustard	255.97	0	0	0.63%	N/A	N/A
Burhinus grallarius	Bush Stone-curlew	907.03	651.31	0	0.37%	0.31%	N/A
Woodland birds - ground and midstorey foraging (passerines)							
Artamus cyanopterus cyanopterus	Dusky Woodswallow	1,663.39	1,407.42	0	0.49%	0.47%	N/A
Chthonicola sagittata	Speckled Warbler	907.28	651.31	0	0.36%	0.31%	N/A
Daphoenositta chrysoptera	Varied Sittella	1,411.94	1,411.94	0	0.47%	0.47%	N/A
Melanodryas cucullata	Hooded Robin	1,663.39	1,407.42	0	0.49%	0.47%	N/A
Pachycephala inornata	Gilbert's Whistler	1,412.19	1,411.94	0	0.46%	0.47%	N/A

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Cumulative impact (ha)			Percentage cumulatively impacted in the study region		
Petroica boodang	Scarlet Robin	1,629.79	1,373.82	0	0.50%	0.48%	N/A
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	1,701.51	1,411.94	0	0.48%	0.47%	N/A
Stagonopleura guttata	Diamond Firetail	907.28	651.31	0	0.36%	0.31%	N/A
Woodland birds - canopy foraging (excluding parrots)							
Anthochaera phrygia	Regent Honeyeater	1,196.04	0	0	0.49%	N/A	N/A
Grantiella picta	Painted Honeyeater	1,412.19	1,411.94	0	0.46%	0.47%	N/A
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	1,374.07	1,373.82	0	0.47%	0.48%	N/A
Wetland or aquatic birds							
Anseranas semipalmata	Magpie Goose	0.25	0.25	0	0.00%	0.00%	N/A
Botaurus poiciloptilus	Australasian Bittern	0.25	0	0	0.00%	N/A	N/A
Ephippiorhynchus asiaticus	Black-necked Stork	0.25	0.25	0	0.00%	0.00%	N/A
Grus rubicunda	Brolga	255.97	0	0	0.63%	N/A	N/A
Oxyura australis	Blue-billed Duck	0.25	0.25	0	0.00%	0.00%	N/A
Rostratula australis	Australian Painted Snipe	0.25	0.25	0	0.00%	0.00%	N/A
Stictonetta naevosa	Freckled Duck	0.25	0.25	0	0.00%	0.00%	N/A
Mammals – unique habitat requirements							
Aepyprymnus rufescens	Rufous Bettong	907.03	651.31	0	0.37%	0.31%	N/A
Dasyurus maculatus	Spotted-tailed Quoll	1,701.51	1,411.94	0	0.48%	0.47%	N/A
Macropus dorsalis	Black-striped Wallaby	1,701.51	1,701.51	0	0.48%	0.48%	N/A
Phascolarctos cinereus	Koala	663.15	663.15	1,701.26	0.66%	0.66%	0.51%
Pseudomys pilligaensis	Pilliga Mouse	410.80 (secondary)	355.82 (primary)	1018.97	0.56% (secondary)	0.48% (primary)	0.36%
Sminthopsis macroura	Stripe-faced Dunnart	1,049.65	1,049.65	0	0.76%	0.76%	N/A
Arboreal hollow-dependent fauna							
Cercartetus nanus	Eastern Pygmy-Possum	1,171.10	1,171.10	0	0.51%	0.51%	N/A
Petaurus norfolcensis	Squirrel Glider	1,373.82	1,373.82	0	0.48%	0.48%	N/A
Predominantly tree-roosting bats							

Scientific Name	Common Name	Foraging	Breeding	Other*	Foraging	Breeding	Other*
		Cumulative impact (ha)			Percentage cumulatively impacted in the study region		
Chalinolobus picatus	Little Pied Bat	1,445.54	1,411.94	0	0.46%	0.47%	N/A
Nyctophilus corbeni (syn. Nyctophilus timoriensis (South-eastern form))	Greater Long-eared Bat	1,411.94	1,411.94	0	0.47%	0.47%	N/A
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	1,701.26	1,411.94	0	0.49%	0.47%	N/A
Predominantly cave-roosting bats							
Chalinolobus dwyeri	Large-eared Pied Bat	1,411.94	0	0	0.47%	N/A	N/A
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	1,701.51	0	0	0.48%	N/A	N/A
Vespadelus troughtoni	Eastern Cave Bat	1,411.94	0	0	0.47%	N/A	N/A
Reptiles							
Hoplocephalus bitorquatus	Pale-headed Snake	1,411.94	1,411.94	0	0.47%	0.47%	N/A
Migratory birds							
Apus pacificus	Fork-tailed Swift	1,701.51	0	0	0.48%	N/A	N/A
Ardea ibis	Cattle Egret	255.97	0	0	0.63%	N/A	N/A
Ardea modesta,	Great Egret	255.97	0	0	0.63%	N/A	N/A
Calidris acuminata	Sharp-tailed Sandpiper	0.25	0	0	0.00%	N/A	N/A
Gallinago hardwickii	Latham's Snipe	0.25	0.25	0	0.00%	0.00%	N/A
Hirundapus caudacutus	White-throated Needletail	1,701.51	0	1,411.94	0.48%	N/A	0.47%
Merops ornatus	Rainbow Bee-eater	1,663.39	1,374.07	0	0.49%	0.47%	N/A
Myiagra cyanoleuca	Satin flycatcher	1,374.07	0	0	0.47%	N/A	N/A
Plegadis falcinellus	Glossy Ibis	0.25	0.25	0	0%	0%	N/A

* Other: Pilliga Mouse/Koala – dispersal habitat; White-throated Needletail: roosting. For the majority of species, roosting habitat is contained within breeding and foraging habitat.

Appendix B: Flora species list

Flora species recorded within the study area

1. Families are grouped under the headings 1. Pteridophytes, 2. Gymnosperms, 3. Dicotyledons, 4. Monocotyledons.
2. An '*' before species indicates exotic species
3. Cover Abundance + = few, small cover (<5%), r = solitary, small cover (<5%), 1 = numerous (<5%), 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = >75%.
4. An 'X' indicates presence
5. Not all species can be accurately identified to species level due to absence of flowering or fruiting material.

Family	Species	Common name	TSC Act Status	EPBC Act Status	Meander	1	2	3	4	5	6	7
1. Pteridophytes												
Marsileaceae	Marsilea costulifera											
Marsileaceae	Marsilea sp.	Nardoo										
Sinopteridaceae	Cheilanthes austrotenuifolia	Rock Fern										
Sinopteridaceae	Cheilanthes distans	Bristly Cloak-fern										
Sinopteridaceae	Cheilanthes sieberi subsp. sieberi	Rock Fern			X	X	X	X	X		X	X
2. Gymnosperms												
Cupressaceae	Callitris endlicheri	Black Cypress-pine										X
Cupressaceae	Callitris glaucophylla	White Cypress-pine			X			X				
Zamiaceae	Macrozamia glaucophylla											
Zamiaceae	Macrozamia heteromera	Burrawang										
Zamiaceae	Macrozamia sp.									X		
3. Dicotyledons												
Acanthaceae	Brunoniella australis	Blue Trumpet, Blue Yam					X					
Acanthaceae	Pseuderanthemum variabile	Pastel Flower										
Acanthaceae	Rostellularia adscendens											
Aizoaceae	Glinus lotoides											
Aizoaceae	Glinus oppositifolius											
Aizoaceae	Tetragonia tetragonioides	New Zealand Spinach, Native Spinach										
Aizoaceae	* Trianthema portulacastrum	Giant Pigweed, Black Pigweed										
Aizoaceae	Trianthema triquetra	Small Hogweed										
Amaranthaceae	Alternanthera angustifolia											
Amaranthaceae	Alternanthera denticulata	Common Joyweed										
Amaranthaceae	Alternanthera nana	Hairy Joyweed										
Amaranthaceae	* Alternanthera pungens	Khaki Weed										
Amaranthaceae	* Alternanthera sp. (unidentified)											
Amaranthaceae	Alternanthera sp. A	Joyweed										
Amaranthaceae	* Amaranthus sp.	Amaranth										
Amaranthaceae	* Gomphrena celosioides	Gomphrena Weed										
Amaranthaceae	Ptilotus semilanatus	Lambs' Tails, Purple Tails										
Amaryllidaceae	(Amaryllidaceae genus unknown)											
Apiaceae	(Apiaceae genus unknown)											
Apiaceae	Actinotus gibbonsii				X					X		
Apiaceae	Actinotus helianthi	Flannel Flower			X							
Apiaceae	Centella asiatica	Pennywort										
Apiaceae	Cyclospermum leptophyllum	Slender Celery										
Apiaceae	Daucus carota	Carrot										
Apiaceae	Daucus glochidiatus	Native Carrot										
Apiaceae	Eryngium paludosum	Long Eryngium										
Apiaceae	Platysace ericoides				X							
Apiaceae	Platysace lanceolata	Lance-leaf Platysace										
Apiaceae	Trachymene incisa											
Apocynaceae	Alstonia constricta	Bitter Bark, Quinine Tree										
Apocynaceae	* Gomphocarpus fruticosus	Narrow-leaved Cotton Bush										
Apocynaceae	Marsdenia viridiflora	Native Pear										
Apocynaceae	Parsonsia eucalyptophylla	Gargaloo, Monkey Vine										
Apocynaceae	Parsonsia sp. (unidentified)											
Apocynaceae	Parsonsia straminea	Common Silkpod, Monkey Rope										
Apocynaceae	Rhyncharrhena linearis	Climbing Purple-star										
Apocynaceae	Tylophora linearis		V	E								
Araliaceae	Astrotricha longifolia	Longleaf Star-hair			X							
Asteraceae	(Asteraceae genus unknown)											
Asteraceae	Actinobole uliginosum	Flannel Cudweed										
Asteraceae	* Arctotheca calendula	Capeweed										
Asteraceae	* Aster sp. (unidentified)											
Asteraceae	* Aster subulatus	Wild Aster										
Asteraceae	* Bidens pilosa	Farmer's Friend, Cobblers Pegs										
Asteraceae	* Bidens sp.											
Asteraceae	* Bidens subalternans	Greater Beggar's Ticks										X
Asteraceae	Brachyscome ciliaris var. subintegrifolia	Variable Daisy, Fringed Daisy										
Asteraceae	Brachyscome curvicarpa											
Asteraceae	Brachyscome diversifolia var. dissecta											
Asteraceae	Brachyscome leptocarpa	Small Hairy Daisy										
Asteraceae	Brachyscome multifida var. multifida	Cut-leaf Daisy										
Asteraceae	Brachyscome nodosa				X							
Asteraceae	Brachyscome sp.											
Asteraceae	Calocephalus sonderi	Pale Beauty-heads										
Asteraceae	Calotis cuneifolia	Purple Burr-daisy										
Asteraceae	Calotis hispidula	Bogan Flea										
Asteraceae	Calotis lappulacea	Yellow Burr-daisy										
Asteraceae	Calotis sp.	Burr-daisy										
Asteraceae	* Carthamus lanatus	Saffron Thistle										
Asteraceae	Cassinia arcuata	Sifton Bush, Chinese-shrub			X		X	X				
Asteraceae	Cassinia laevis	Cough-bush										
Asteraceae	Cassinia sp.											
Asteraceae	* Centaurea melitensis	Maltese Cockspur										
Asteraceae	Centipeda cunninghamii	Common Sneezeweed										
Asteraceae	Centipeda elatinoides											
Asteraceae	Centipeda minima var. minima	Spreading Sneezeweed										
Asteraceae	Centipeda pleiocephala	Tall Sneezeweed										
Asteraceae	Centipeda sp.	Sneezeweed										
Asteraceae	Centipeda thespidioides	Desert Sneezeweed										
Asteraceae	* Chondrilla juncea	Skeleton Weed										
Asteraceae	Chrysocephalum apiculatum	Common Everlasting, Yellow Buttons			X			X	X			
Asteraceae	Chrysocephalum semipapposum	Clustered Everlasting, Yellow Buttons										
Asteraceae	* Cirsium vulgare	Black Thistle, Spear Thistle										
Asteraceae	* Conyza bonariensis	Flaxleaf Fleabane										
Asteraceae	* Conyza sp.				X			X	X			
Asteraceae	* Conyza sumatrensis	Tall Fleabane										
Asteraceae	Coronidium oxylepis						X			X		
Asteraceae	Coronidium sp.											
Asteraceae	Cotula australis	Common Cotula										
Asteraceae	Eclipta platyglossa	Yellow Twin-heads										
Asteraceae	Epaltes australis	Spreading Nut-heads			X							
Asteraceae	Euchiton sp.	Cudweed										
Asteraceae	Euchiton sphaericus				X			X		X		X
Asteraceae	* Gamochaeta calviceps	Cudweed										
Asteraceae	* Gamochaeta sp.											
Asteraceae	Glossogyne tannensis	Cobbler's Tack										
Asteraceae	Gnephosis tenuissima	Dwarf Cup-flower										
Asteraceae	* Hedypnois rhagadioloides subsp. cretica	Cretan Weed										
Asteraceae	* Helianthus annuus	Sunflower										
Asteraceae	* Hypochaeris microcephala var. albiflora	White Flatweed										
Asteraceae	* Hypochaeris radicata	Catsear, False Dandelion										
Asteraceae	Isoetopsis graminifolia	Grass Cushions										
Asteraceae	* Lactuca serriola	Prickly Lettuce, Compass Plant										
Asteraceae	Lagenophora gracilis											
Asteraceae	Leiocarpa panaetioides	Wooly Buttons										
Asteraceae	Leiocarpa sp.											
Asteraceae	Minuria integerrima	Smooth Minuria										
Asteraceae	Myriocephalus pluriflorus	Woolly-heads										
Asteraceae	Olearia decurrens	Clammy Daisy-bush										
Asteraceae	Olearia ramulosa											
Asteraceae	Ozothamnus diosmifolius	White Dogwood			X		X				X	
Asteraceae	Podolepis jaceoides	Showy Copper-wire Daisy										
Asteraceae	Podolepis neglecta											
Asteraceae	Podolepis sp. (unidentified)							X				
Asteraceae	Pseudognaphalium luteoalbum	Jersey Cudweed										
Asteraceae	Pycnosorus globosus	Drumsticks										
Asteraceae	Pycnosorus sp.											
Asteraceae	Senecio quadridentatus	Cotton Fireweed										
Asteraceae	Senecio sp.	Groundsel										
Asteraceae	Solenogyne bellioides											
Asteraceae	* Soliva anthemifolia	Dwarf Jo-jo, Button Burrweed										
Asteraceae	* Soliva sessilis	Bindii, Bindi-eye, Jo-Jo										
Asteraceae	* Sonchus asper	Prickly Sow-thistle, Rough Milk-thistle										
Asteraceae	* Sonchus oleraceus	Common Sow-thistle, Milk-thistle			X				X			X
Asteraceae	Stuartina muelleri	Spoon Cudweed										
Asteraceae	* Tagetes minuta	Stinking Roger										
Asteraceae	* Taraxacum officinale	Dandelion										
Asteraceae	Triptilodiscus pygmaeus	Common Sunray										
Asteraceae	* Verbesina encelioides	Crownbeard										
Asteraceae	Vernonia cinerea						X	X	X	X		X
Asteraceae	Vittadinia cervicularis											
Asteraceae	Vittadinia cuneata var. cuneata	Fuzzweed										
Asteraceae	Vittadinia dissecta var. hirta	Fuzzweed						X		X		
Asteraceae	Vittadinia muelleri	Fuzzweed										
Asteraceae	Vittadinia pterochaeta	Rough Fuzzweed										
Asteraceae	Vittadinia pustulata											
Asteraceae	Vittadinia sp.	Fuzzweed						X		X		X
Asteraceae	Vittadinia sulcata											
Asteraceae	* Xanthium italicum	Hunter Burr										
Asteraceae	* Xanthium occidentale	Noogoora Burr										
Asteraceae	* Xanthium sp.											
Asteraceae	Xerochrysum viscosum	Common Everlasting, Golden Everlasting				X						
Boraginaceae	Cynoglossum suaveolens	Native Hound's-tongue										
Boraginaceae	* Heliotropium amplexicaule	Blue Heliotrope										
Brassicaceae	(Brassicaceae genus unknown)											
Brassicaceae	* Lepidium africanum	Common Peppercress										
Brassicaceae	Lepidium aschersonii		V	V								
Brassicaceae	* Lepidium bonariense	Cut-leaf Peppercress										
Brassicaceae	Lepidium monoplocoides	Winged Peppercress	E	E	X							
Brassicaceae	* Lepidium sp.											
Brassicaceae	* Rapistrum rugosum	Turnip Weed, Giant Mustard										
Cactaceae	* Cereus sp. (unidentified)											
Cactaceae	* Opuntia aurantiaca	Tiger Pear										
Cactaceae	* Opuntia stricta	Prickly Pear, Common Pest Pear										
Cactaceae	* Opuntia tomentosa	Prickly Pear, Velvet Tree Pear										
Campanulaceae	Wahlenbergia communis	Australian Bluebell										
Campanulaceae	Wahlenbergia fluminalis	River Bluebell						X				
Campanulaceae	Wahlenbergia gracilenta	Annual Bluebell				X						
Campanulaceae	Wahlenbergia gracilis	Sprawling Bluebell			X							
Campanulaceae	Wahlenbergia sp. (unidentified)	Australian Bluebell			X		X		X			
Campanulaceae	Wahlenbergia stricta											
Campanulaceae	Wahlenbergia stricta subsp. alterna	Tall Bluebell						X				
Campanulaceae	Wahlenbergia stricta subsp. stricta	Tall Bluebell							X			X
Campanulaceae	Wahlenbergia tumidifructa											
Capparaceae	Apophyllum anomalum	Warrior-bush, Currant-bush										
Capparaceae	Capparis lasiantha	Nepine										
Capparaceae	Capparis mitchellii	Wild Orange, Native Orange										
Caryophyllaceae	* (Caryophyllaceae genus unknown											
Caryophyllaceae	Gypsophila australis	Annual Chalkwort										
Caryophyllaceae	Polycarpaea corymbosa var. minor											
Caryophyllaceae	* Polycarpon tetraphyllum	Four-leaf Allseed							X			
Caryophyllaceae	* Silene gallica	French Catchfly										
Caryophyllaceae	Spergularia brevifolia	Lesser Sea-spurrey										
Caryophyllaceae	* Spergularia rubra	Sandspurry										
Casuarinaceae	(Casuarinaceae genus unknown)											
Casuarinaceae	Allocasuarina diminuta subsp. diminuta				X	X						X
Casuarinaceae	Allocasuarina diminuta subsp. diminuta											
Casuarinaceae	Allocasuarina luehmannii	Bulloak			X		X				X	X
Celastraceae	Maytenus cunninghamii	Yellow-berry Bush										
Chenopodiaceae	Atriplex semibaccata	Creeping Saltbush										
Chenopodiaceae	Atriplex sp.	Saltbush										
Chenopodiaceae	Atriplex spinibractea	Spiny-fruit Saltbush										
Chenopodiaceae	Chenopodium desertorum subsp. indet.	Desert Goosefoot										
Chenopodiaceae	Chenopodium pumilio	Small Crumbweed										
Chenopodiaceae	Chenopodium sp.											
Chenopodiaceae	Einadia hastata	Berry Saltbush										
Chenopodiaceae	Einadia nutans	Climbing Saltbush										
Chenopodiaceae	Einadia nutans subsp. linifolia	Climbing Saltbush										
Chenopodiaceae	Einadia nutans subsp. nutans	Climbing Saltbush										
Chenopodiaceae	Einadia polygonoides											
Chenopodiaceae	Einadia sp.											
Chenopodiaceae	Einadia trigonos	Fishweed										X
Chenopodiaceae	Enchylaena tomentosa	Ruby Saltbush										
Chenopodiaceae	Maireana enchylaenoides	Wingless Fissure-weed										
Chenopodiaceae	Maireana microphylla	Eastern Cottonbush										
Chenopodiaceae	Maireana sp.											
Chenopodiaceae	Rhagodia spinescens	Spiny Saltbush										
Chenopodiaceae	Salsola kali var. kali	Roly-Poly, Buckbush, Prickly Saltwort										
Chenopodiaceae	Sclerolaena birchii	Galvanised Burr										
Chenopodiaceae	Sclerolaena diacantha	Grey Copperburr										
Chenopodiaceae	Sclerolaena muricata	Black Rolypoly										
Chenopodiaceae	Sclerolaena sp.											
Chenopodiaceae	Sclerolaena tetracuspis	Brigalow Burr										
Chenopodiaceae	Sclerolaena tricuspis	Three-spined Copperburr										
Chloanthaceae	Chloanthes parviflora				X							
Chloanthaceae	Spartothamnella juncea	Bead Bush										
Clusiaceae	Hypericum gramineum	Small St Johns-wort			X		X	X	X			X
Convolvulaceae	Convolvulus erubescens	Native Bindweed, Blushing Bindweed										
Convolvulaceae	Convolvulus graminetinus											
Convolvulaceae	Convolvulus sp.											
Convolvulaceae	Dichondra repens	Kidney-weed, Mercury Bay Weed						X				X
Convolvulaceae	Dichondra sp. A	Hairy Kidney Weed										
Convolvulaceae	Evolvulus alsinoides											
Convolvulaceae	Evolvulus alsinoides var. decumbens											
Crassulaceae	* Bryophyllum delagoense	Mother-of-Millions										
Crassulaceae	Crassula sieberiana	Australian Stonecrop										
Cucurbitaceae	* Citrullus sp.											
Dilleniaceae	Hibbertia circumdans											
Dilleniaceae	Hibbertia covenyana											
Dilleniaceae	Hibbertia incana											
Dilleniaceae	Hibbertia obtusifolia	Guinea-flower			X	X		X	X			
Dilleniaceae	Hibbertia pedunculata											
Dilleniaceae	Hibbertia riparia	Erect Guinea-flower										X
Dilleniaceae	Hibbertia sp.					X				X		
Droseraceae	Drosera burmannii											
Droseraceae	Drosera peltata	Pale Sundew										
Droseraceae	Drosera sp.	Sundew										
Elatinaceae	Elatine gratioloides	Waterwort										
Ericaceae - Styphelioideae	Brachyloma daphnoides	Daphne Heath			X	X		X	X	X		X
Ericaceae - Styphelioideae	Leucopogon biflorus				X							
Ericaceae - Styphelioideae	Leucopogon muticus	Blunt Beard-heath				X			X			X
Ericaceae - Styphelioideae	Lissanthe strigosa	Peach Heath			X		X	X				X
Ericaceae - Styphelioideae	Melichrus erubescens											
Ericaceae - Styphelioideae	Melichrus sp.											
Ericaceae - Styphelioideae	Melichrus urceolatus	Urn Heath			X	X		X	X	X		X
Ericaceae - Styphelioideae	Styphelia sp. (unidentified)											
Ericaceae - Styphelioideae	Styphelia triflora	Pink Fivecorners										
Euphorbiaceae	Bertya gummifera											
Euphorbiaceae	Bertya opponens		V	V								
Euphorbiaceae	Chamaesyce drummondii	Caustic Weed, Flat Spurge						X				
Euphorbiaceae	Phyllanthus carpentariae											
Euphorbiaceae	Phyllanthus sp.											
Euphorbiaceae	Phyllanthus virgatus						X		X			
Euphorbiaceae	Poranthera microphylla	Small Poranthera			X	X		X	X	X		
Euphorbiaceae	Ricinocarpos bowmannii	Northern Wedding Bush										
Euphorbiaceae	* Ricinus communis	Castor Oil Plant										
Euphorbiaceae	Sauropus ramosissimus											
Fabaceae	(Fabaceae genus unknown)					X						
Fabaceae Caesalpinioideae	Senna artemisioides subsp. petiolaris	Woody Senna										
Fabaceae Caesalpinioideae	Senna artemisioides subsp. zygophylla	Punty Bush										
Fabaceae Caesalpinioideae	Senna barclayana	Smooth Senna										
Fabaceae Faboideae	Aotus mollis											
Fabaceae Faboideae	Aotus sp.											
Fabaceae Faboideae	Aotus subglauca											
Fabaceae Faboideae	Aotus subglauca var. filiformis											
Fabaceae Faboideae	Bossiaea obcordata	Spiny Bossiaea										
Fabaceae Faboideae	Bossiaea rhombifolia subsp. concolor				X	X						
Fabaceae Faboideae	Chorizema parviflorum	Eastern Flame Pea										
Fabaceae Faboideae	Crotalaria mitchellii	Yellow Rattlepod								X		
Fabaceae Faboideae	Daviesia acicularis	Sandplain Bitter-pea										
Fabaceae Faboideae	Daviesia genistifolia	Broom Bitter Pea										
Fabaceae Faboideae	Daviesia sp.											
Fabaceae Faboideae	Daviesia ulicifolia	Gorse Bitter-pea										
Fabaceae Faboideae	Desmodium brachypodum	Large Tick-trefoil							X			X
Fabaceae Faboideae	Desmodium sp.											
Fabaceae Faboideae	Desmodium varians	Slender Tick-trefoil										
Fabaceae Faboideae	Dillwynia sericea	Showy Parrot-pea, Eggs-and-bacon				X				X		
Fabaceae Faboideae	Dillwynia sericea glabriflora											
Fabaceae Faboideae	Dillwynia sp.	Eggs-and-bacon Pea										
Fabaceae Faboideae	Glycine canescens	Silky Glycine							X			
Fabaceae Faboideae	Glycine clandestina	Twining Glycine			X		X	X	X			X
Fabaceae Faboideae	Glycine sp.							X				
Fabaceae Faboideae	Glycine stenophita											
Fabaceae Faboideae	Glycine tabacina	Variable Glycine										
Fabaceae Faboideae	Gompholobium foliolosum	Fern-leaved Burtonia										
Fabaceae Faboideae	Gompholobium virgatum var. aspalathoides											
Fabaceae Faboideae	Hardenbergia violacea	False Sarsaparilla			X							
Fabaceae Faboideae	Hovea lanceolata	Lance-leaf Hovea										
Fabaceae Faboideae	Indigofera adesmiifolia											
Fabaceae Faboideae	Indigofera australis	Native Indigo										
Fabaceae Faboideae	Jacksonia scoparia	Dogwood										
Fabaceae Faboideae	Kennedia procurrens	Purple Running Pea										
Fabaceae Faboideae	* Medicago sp.	Medic										
Fabaceae Faboideae	Mirbelia pungens											
Fabaceae Faboideae	Pultenaea cinerascens										X	
Fabaceae Faboideae	Pultenaea foliolosa				X		X					
Fabaceae Faboideae	Pultenaea sp. (unidentified)						X					
Fabaceae Faboideae	Swainsona cadellii											
Fabaceae Faboideae	Swainsona galegifolia	Smooth Darling Pea										
Fabaceae Faboideae	Swainsona monticola											
Fabaceae Faboideae	Swainsona sp.	Darling Pea										
Fabaceae Faboideae	Templetonia stenophylla	Leafy Templetonia										
Fabaceae Faboideae	* Trifolium campestre	Hop Clover										
Fabaceae Faboideae	* Trifolium glomeratum	Clustered Clover										
Fabaceae Faboideae	* Vicia sp. (unidentified)											
Fabaceae Faboideae	Zornia dyctiocarpa	Zornia					X					
Fabaceae Faboideae	Zornia sp.											
Fabaceae Mimosoideae	Acacia burrowii	Burrow's Wattle										
Fabaceae Mimosoideae	Acacia buxifolia subsp. buxifolia	Box-leaved Wattle										
Fabaceae Mimosoideae	Acacia caroleae				X	X						
Fabaceae Mimosoideae	Acacia cheelii	Motherumbah										
Fabaceae Mimosoideae	Acacia crassa											
Fabaceae Mimosoideae	Acacia deanei subsp. deanei	Green Wattle, Deane's Wattle						X	X			X
Fabaceae Mimosoideae	Acacia debilis											
Fabaceae Mimosoideae	Acacia doratoxylon	Currawang, Lancewood, Spearwood										
Fabaceae Mimosoideae	Acacia flexifolia	Bent-leaf Wattle										
Fabaceae Mimosoideae	Acacia gladiiformis	Wattle			X	X						
Fabaceae Mimosoideae	Acacia hakeoides	Western Black Wattle										
Fabaceae Mimosoideae	Acacia harpophylla	Brigalow										
Fabaceae Mimosoideae	Acacia implexa	Hickory Wattle										

Family	Species	Common name	TSC Act Status	EPBC Act Status	Meander
Fabaceae Mimosoideae	*Acacia leiocalyx* subsp. *leiocalyx*	Curracabah			
Fabaceae Mimosoideae	*Acacia leucoclada* subsp. *leucoclada*	Northern Silver Wattle			
Fabaceae Mimosoideae	*Acacia lineata*				
Fabaceae Mimosoideae	*Acacia mariae*	Golden-top Wattle			
Fabaceae Mimosoideae	*Acacia oswaldii*	Miljee			
Fabaceae Mimosoideae	*Acacia penninervis*	Mountain Hickory			
Fabaceae Mimosoideae	*Acacia pilligaensis*				X
Fabaceae Mimosoideae	*Acacia polybotrya*	Western Silver Wattle			
Fabaceae Mimosoideae	*Acacia pravifolia*	Coil-pod Wattle			
Fabaceae Mimosoideae	*Acacia sertiformis*				
Fabaceae Mimosoideae	*Acacia* sp.				
Fabaceae Mimosoideae	*Acacia spectabilis*	Mudgee Wattle			X
Fabaceae Mimosoideae	*Acacia tindaleae*	Golden-top Wattle			X
Fabaceae Mimosoideae	*Acacia triptera*	Spurwing Wattle			
Fabaceae Mimosoideae	*Acacia triptera X cheelii*				
Fabaceae Mimosoideae	*Neptunia gracilis*				
Fabaceae Mimosoideae	*Vachellia farnesiana*	Mimosa Bush			
Fumariaceae	* *Fumaria* sp.	Fumitory			
Gentianaceae	* *Centaurium* sp.	Centaury			
Gentianaceae	* *Centaurium tenuiflorum*	Centaury			
Gentianaceae	*Schenkia spicata*	Spike Centaury			X
Gentianaceae	*Schenkia spicata*	Spike Centaury			
Goodeniaceae	*Brunonia australis*	Blue Pincushion			
Goodeniaceae	*Dampiera adpressa*	Purple Beauty-bush			X
Goodeniaceae	*Dampiera lanceolata*				
Goodeniaceae	*Dampiera* sp.				
Goodeniaceae	*Dampiera stricta*				
Goodeniaceae	*Goodenia bellidifolia*				
Goodeniaceae	*Goodenia cycloptera*	Serrated Goodenia			X
Goodeniaceae	*Goodenia fascicularis*	Silky Goodenia			
Goodeniaceae	*Goodenia glabra*				
Goodeniaceae	*Goodenia hederacea*	Ivy Goodenia, Forest Goodenia			
Goodeniaceae	*Goodenia macbarronii*				
Goodeniaceae	*Goodenia paniculata*				X
Goodeniaceae	*Goodenia pusilliflora*	Small-flowered Goodenia			
Goodeniaceae	*Goodenia rotundifolia*				X
Goodeniaceae	*Goodenia* sp.				
Goodeniaceae	*Scaevola spinescens*				
Haloragaceae	*Gonocarpus elatus*	Hill Raspwort			
Haloragaceae	*Gonocarpus* sp.	Raspwort			
Haloragaceae	*Gonocarpus teucrioides*	Raspwort			X
Haloragaceae	*Haloragis heterophylla*	Raspwort			
Haloragaceae	*Haloragis* sp.				
Haloragaceae	*Myriophyllum implicatum*		CE		
Lamiaceae	*Ajuga australis*	Native Bugle, Australian Bugle			
Lamiaceae	* *Marrubium vulgare*	Horehound			
Lamiaceae	*Prostanthera granitica*	Granite Mintbush			
Lamiaceae	*Prostanthera howelliae*				
Lamiaceae	*Prostanthera ringens*	Green-flowered Mint-bush			
Lamiaceae	*Prostanthera* sp.				
Lamiaceae	*Scutellaria humilis*	Dwarf Skullcap			
Lamiaceae	*Westringia cheelii*				
Lauraceae	*Cassytha glabella*	Devil's Twine, Dodder-laurel			
Lauraceae	*Cassytha pubescens*	Devil's Twine, Dodder-laurel			
Lauraceae	*Cassytha* sp.	Devil's Twine, Dodder-laurel			
Linaceae	*Linum marginale*	Native Flax, Wild Flax			
Loganiaceae	*Mitrasacme paludosa*				
Loranthaceae	*Amyema bifurcata*				
Loranthaceae	*Amyema cambagei*	She-oak Mistletoe			
Loranthaceae	*Amyema gaudichaudii*	Paperbark Mistletoe			
Loranthaceae	*Amyema linophylla* subsp. *orientalis*				
Loranthaceae	*Amyema miquelii*	Box Mistletoe, Drooping Mistletoe			
Loranthaceae	*Amyema miraculosum*	Fleshy Mistletoe, Round-leaf Mistletoe			
Loranthaceae	*Amyema pendulum*	Drooping Mistletoe			
Loranthaceae	*Amyema quandang* var. *quandang*	Grey Mistletoe			
Loranthaceae	*Amyema* sp.	Mistletoe			
Loranthaceae	*Dendrophthoe glabrescens*				
Lythraceae	*Lythrum hyssopifolia*	Hyssop Loosestrife			
Malvaceae	*Abutilon macrum*				
Malvaceae	*Abutilon oxycarpum*				
Malvaceae	*Abutilon* sp.				
Malvaceae	*Hibiscus brachysiphonius*	Low hibiscus			
Malvaceae	*Hibiscus sturtii*	Hill Hibiscus			
Malvaceae	*Malvastrum coromandelianum*	Prickly Malvastrum			
Malvaceae	*Sida corrugata*	Corrugated Sida, Sage Weed			
Malvaceae	*Sida cunninghamii*	Ridge Sida			
Malvaceae	*Sida fibulifera*	Pin Sida			
Malvaceae	* *Sida rhombifolia*	Paddy's Lucerne			
Malvaceae	*Sida* sp. (unidentified)				
Malvaceae	*Sida spinosa*				
Malvaceae	*Sida trichopoda*	High Sida			
Myoporaceae	*Eremophila debilis*	Winter Apple, Amulla			
Myoporaceae	*Eremophila deserti*	Turkey-bush			
Myoporaceae	*Eremophila longifolia*	Emu-bush			
Myoporaceae	*Eremophila mitchellii*	Budda			
Myoporaceae	*Myoporum montanum*	Waterbush, Western Boobialla			
Myoporaceae	*Myoporum* sp.				
Myrtaceae	*Angophora floribunda*	Rough-barked Apple			X
Myrtaceae	*Babingtonia densifolia*				
Myrtaceae	*Callistemon linearis*	Narrow-leaved Bottlebrush			
Myrtaceae	*Callistemon* sp.	Bottlebrush			
Myrtaceae	*Calytrix tetragona*	Fringe-myrtle			X
Myrtaceae	*Corymbia tessellaris*	Carbeen, Moreton Bay Ash			
Myrtaceae	*Corymbia trachyphloia*	Brown Bloodwood			X
Myrtaceae	*Eucalyptus beyeriana*	Beyer's Ironbark			
Myrtaceae	*Eucalyptus blakelyi*	Blakely's Red Gum			X
Myrtaceae	*Eucalyptus camaldulensis*	River Red Gum			X
Myrtaceae	*Eucalyptus chloroclada*	Dirty Gum			X
Myrtaceae	*Eucalyptus conica*	Fuzzy Box			
Myrtaceae	*Eucalyptus crebra*	Narrow-leaved Ironbark			X
Myrtaceae	*Eucalyptus dealbata*	Tumbledown Red Gum			
Myrtaceae	*Eucalyptus dumosa*	White Mallee			
Myrtaceae	*Eucalyptus dwyeri*	Dwyer's Red Gum			X
Myrtaceae	*Eucalyptus fibrosa*	Broad-leaved Red Ironbark			X
Myrtaceae	*Eucalyptus macrorhyncha*	Red Stringybark			
Myrtaceae	*Eucalyptus melanophloia*	Silver-leaved Ironbark			
Myrtaceae	*Eucalyptus melliodora*	Yellow Box			X
Myrtaceae	*Eucalyptus melliodora X sideroxylon*	Yellow Box X Mugga Ironbark			
Myrtaceae	*Eucalyptus microcarpa*	Western Grey Box			X
Myrtaceae	*Eucalyptus nubila*				
Myrtaceae	*Eucalyptus pilligaensis*	Narrow-leaved Grey Box			
Myrtaceae	*Eucalyptus populnea* subsp. *bimbil*	Bimble Box, Poplar Box			
Myrtaceae	*Eucalyptus rossii*	Inland Scribbly Gum			X
Myrtaceae	*Eucalyptus sideroxylon*	Mugga, Red Ironbark			
Myrtaceae	*Eucalyptus* sp.				
Myrtaceae	*Eucalyptus viridis*	Green Mallee			
Myrtaceae	*Homoranthus flavescens*				X
Myrtaceae	*Leptospermum parvifolium*	Small-leaved Tea-tree			
Myrtaceae	*Leptospermum polygalifolium* subsp. *transmontanum*	Tantoon			X
Myrtaceae	*Leptospermum polygalifolium* subsp. *polygalifolium*	Yellow Tea-tree, Tantoon Tea-Tree			
Myrtaceae	*Leptospermum* sp.	Tea-tree			
Myrtaceae	*Melaleuca erubescens*				
Myrtaceae	*Melaleuca thymifolia*	Thyme Honey-myrtle			X
Myrtaceae	*Melaleuca uncinata*	Broom Honeymyrtle			X
Myrtaceae	*Micromyrtus sessilis*				
Myrtaceae	*Sannantha cunninghamii*				X
Nyctaginaceae	*Boerhavia coccinea*	Tar Vine			
Nyctaginaceae	*Boerhavia dominii*	Tar Vine			
Nyctaginaceae	*Boerhavia* sp.				
Olacaceae	*Olax stricta*	Olax			
Oleaceae	*Jasminum didymum*				
Oleaceae	*Jasminum lineare*	Desert Jasmine			
Oleaceae	*Jasminum suavissimum*	Sweet Jasmine, Spicy Jasmine			
Oleaceae	*Notelaea microcarpa*	Native Olive			
Oleaceae	*Notelaea* sp. (unidentified)				
Oleaceae	* *Olea europaea* subsp. *cuspidata*	African Olive			
Onagraceae	*Epilobium hirtigerum*				
Onagraceae	*Ludwigia peploides* subsp. *montevidensis*	Water Primrose			
Onagraceae	* *Oenothera indecora* subsp. *bonariensis*				
Oxalidaceae	*Oxalis perennans*	Oxalis			X
Oxalidaceae	*Oxalis radicosa*				
Oxalidaceae	* *Oxalis* sp.				
Papaveraceae	* *Argemone ochroleuca*	Mexican Poppy			
Pittosporaceae	*Bursaria spinosa*	Australian Boxthorn			
Pittosporaceae	*Pittosporum angustifolium*	Berrigan, Weeping Pittosporum			
Pittosporaceae	*Pittosporum angustifolium*	Berrigan, Weeping Pittosporum			
Plantaginaceae	*Plantago cunninghamii*	Sago-weed			
Plantaginaceae	*Plantago debilis*				
Plantaginaceae	*Plantago* sp.				
Polygalaceae	*Polygala linariifolia*		E		
Polygonaceae	* *Emex australis*	Spiny Emex, Doublegee			
Polygonaceae	*Persicaria decipiens*	Slender Knotweed			
Polygonaceae	*Persicaria prostrata*	Creeping Knotweed			
Polygonaceae	*Persicaria* sp.	Knotweed			
Polygonaceae	* *Polygonum arenastrum*	Wireweed			
Polygonaceae	* *Polygonum aviculare*	Wire Weed			
Polygonaceae	*Polygonum* sp.				
Polygonaceae	*Rumex brownii*	Slender Dock			
Polygonaceae	* *Rumex crispus*	Curled Dock			
Polygonaceae	* *Rumex* sp.	Dock			
Portulacaceae	*Calandrinia eremaea*	Small Purslane			
Portulacaceae	*Calandrinia* sp.				
Portulacaceae	*Portulaca oleracea*	Pigweed, Purslane			
Portulacaceae	* *Portulaca pilosa*				
Portulacaceae	*Portulaca* sp.				
Primulaceae	* *Anagallis arvensis*	Pimpernel			
Proteaceae	*Conospermum taxifolium*	Smoke Bush			
Proteaceae	*Grevillea floribunda*	Rusty Spider-flower			X
Proteaceae	*Grevillea striata*	Beefwood			X
Proteaceae	*Isopogon petiolaris*				X
Proteaceae	*Persoonia cuspidifera*				X
Proteaceae	*Persoonia sericea*				
Proteaceae	*Persoonia* sp.				
Ranunculaceae	*Myosurus minimus* var. *australis*	Mousetail			
Rhamnaceae	*Alphitonia excelsa*	Red Ash, Soap Tree			
Rhamnaceae	*Cryptandra amara* var. *amara*				X
Rhamnaceae	*Cryptandra amara* var. *longiflora*				
Rhamnaceae	*Pomaderris queenslandica*		E		
Rubiaceae	(Rubiaceae genus unknown)				
Rubiaceae	*Asperula conferta*	Common Woodruff			
Rubiaceae	*Asperula cunninghamii*				
Rubiaceae	* *Galium aparine*	Cleavers, Goose-grass, Bedstraw			
Rubiaceae	*Galium gaudichaudii*	Rough Bedstraw			
Rubiaceae	*Opercularia diphylla*	Stinkweed			X
Rubiaceae	*Opercularia* sp.				
Rubiaceae	*Pomax umbellata*	Pomax			X
Rubiaceae	*Psydrax oleifolia*	Wild Lemon			
Rutaceae	*Boronia bipinnata*	Rock Boronia			X
Rutaceae	*Boronia glabra*				X
Rutaceae	*Boronia* sp.				
Rutaceae	*Geijera parviflora*	Wilga			
Rutaceae	*Phebalium squamulosum*	Scaly Phebalium			
Rutaceae	*Philotheca ciliata*				
Rutaceae	*Philotheca difformis*				
Rutaceae	*Philotheca salsolifolia*	Philotheca			
Rutaceae	*Zieria aspalathoides*				
Salicaceae	* *Salix babylonica*	Weeping Willow			
Santalaceae	*Exocarpos aphyllus*	Leafless Ballart			
Santalaceae	*Exocarpos cupressiformis*	Cherry Ballart, Native Cherry			
Santalaceae	*Exocarpos* sp.				
Sapindaceae	*Alectryon oleifolius* subsp. *elongatus*	Western Rosewood, Boonaree			
Sapindaceae	*Dodonaea boroniifolia*	Fern-leaf Hopbush, Hairy Hopbush			X
Sapindaceae	*Dodonaea falcata*				
Sapindaceae	*Dodonaea heteromorpha*	Propellor Bush			
Sapindaceae	*Dodonaea peduncularis*	Stalked Hopbush			
Sapindaceae	*Dodonaea* sp.	Hopbush			
Sapindaceae	*Dodonaea truncatiales*				
Sapindaceae	*Dodonaea viscosa*				
Sapindaceae	*Dodonaea viscosa* subsp. *angustissima*	Narrow-leaf Hopbush			
Sapindaceae	*Dodonaea viscosa* subsp. *cuneata*	Wedge-leaf Hopbush			X
Sapindaceae	*Dodonaea viscosa* subsp. *mucronata*	Sticky Hopbush			
Sapindaceae	*Dodonaea viscosa* subsp. *spatulata*	Sticky Hopbush			
Scrophulariaceae	*Gratiola pedunculata*	Stalked Brooklime			
Scrophulariaceae	* *Veronica peregrina*	Wandering Speedwell			
Scrophulariaceae	*Veronica plebeia*	Creeping Speedwell			
Scrophulariaceae	*Veronica* sp. (unidentified)				
Solanaceae	* *Cestrum parqui*	Green Cestrum			
Solanaceae	* *Lycium ferocissimum*	African Boxthorn			
Solanaceae	*Nicotiana megalosiphon* subsp. *megalosiphon*				
Solanaceae	*Solanum cleistogamum*				
Solanaceae	*Solanum esuriale*	Quena			
Solanaceae	*Solanum ferocissimum*	Spiny Potato-bush			
Solanaceae	*Solanum jucundum*				
Solanaceae	* *Solanum nigrum*	Blackberry Nightshade			
Solanaceae	*Solanum parvifolium* subsp. *parvifolium*				
Solanaceae	* *Solanum* sp.				
Stackhousiaceae	*Stackhousia monogyna*	Creamy Candles			
Stackhousiaceae	*Stackhousia muricata*				X
Stackhousiaceae	*Stackhousia* sp.				
Sterculiaceae	*Brachychiton populneus* subsp. *populneus*	Kurrajong			
Sterculiaceae	*Keraudrenia corrolata*				
Sterculiaceae	*Rulingia procumbens*		V	V	X
Stylidiaceae	*Stylidium eglandulosum*	Trigger-plant			
Thymelaeaceae	*Pimelea linifolia*	Rice Flower			X
Thymelaeaceae	*Pimelea linifolia* subsp. *collina*	Rice-flower			
Thymelaeaceae	*Pimelea* sp.				
Urticaceae	*Urtica incisa*	Stinging Nettle, Scrub Nettle			
Verbenaceae	* *Glandularia aristigera*	Mayne's Pest, Moss Verbena			
Verbenaceae	* *Glandularia aristigera*	Mayne's Pest, Moss Verbena			
Verbenaceae	* *Phyla canescens*	Lippia			
Verbenaceae	* *Phyla nodiflora*	Carpet Weed, Lippia			
Verbenaceae	*Verbena gaudichaudii*				
Verbenaceae	* *Verbena incompta*				
Verbenaceae	* *Verbena quadrangularis*				
Verbenaceae	* *Verbena* sp.	Verbena			
Violaceae	*Hybanthus monopetalus*	Slender Violet-bush			X
Violaceae	*Melicytus dentatus*	Tree Violet			
Zygophyllaceae	*Tribulus* sp.	Caltrop, Cat-head			
4. Monocotyledons					
Alliaceae	* *Nothoscordum gracile*	Onion Weed			
Amaryllidaceae	*Crinum flaccidum*	Darling Lily			
Anthericaceae	*Arthropodium milleflorum*	Vanilla Lily			
Anthericaceae	*Arthropodium species B*				
Anthericaceae	*Caesia parviflora*	Pale Grass Lily			X
Anthericaceae	*Dichopogon fimbriatus*	Nodding Chocolate-lily			
Anthericaceae	*Laxmannia gracilis*	Slender Wire Lily			X
Anthericaceae	*Thysanotus tuberosus*	Common Fringe Lily, Fringed Violet			
Anthericaceae	*Tricoryne elatior*	Yellow Rush Lily			X
Asphodelaceae	*Bulbine alata*	Native Leek			
Asphodelaceae	*Bulbine semibarbata*	Leek Lily			
Commelinaceae	(Commelinaceae genus unknown)				
Commelinaceae	*Commelina cyanea*	Blue Spiderwort			
Commelinaceae	*Commelina ensifolia*	Scurvy Grass			
Commelinaceae	*Murdannia graminea*				X
Cyperaceae	(Cyperaceae genus unknown)				
Cyperaceae	*Bulbostylis barbata*				
Cyperaceae	*Carex appressa*	Tall Sedge			
Cyperaceae	*Carex inversa*	Knob Sedge			
Cyperaceae	*Carex* sp.	Sedge			
Cyperaceae	*Cyperus concinnus*	Trim Flat-sedge			
Cyperaceae	* *Cyperus eragrostis*	Drain Flat-sedge, Umbrella Sedge			
Cyperaceae	*Cyperus exaltatus*	Giant Sedge, Tall Flat-sedge			
Cyperaceae	*Cyperus fulvus*	Sticky Sedge			
Cyperaceae	*Cyperus gracilis*	Slender Sedge			X
Cyperaceae	*Cyperus gunnii* subsp. *gunnii*	Flecked Flat-sedge			
Cyperaceae	*Cyperus gymnocaulos*	Spiny Sedge			
Cyperaceae	*Cyperus haspan*				
Cyperaceae	*Cyperus leiocaulon*				
Cyperaceae	*Cyperus procerus*				
Cyperaceae	*Cyperus* sp.				
Cyperaceae	*Cyperus vaginatus*				
Cyperaceae	*Eleocharis pallens*	Pale Spike-rush			
Cyperaceae	*Eleocharis plana*	Ribbed Spike-rush			
Cyperaceae	*Eleocharis* sp.	Spike-rush			
Cyperaceae	*Fimbristylis dichotoma*				X
Cyperaceae	*Gahnia aspera*	Rough-leaved Saw-sedge			X
Cyperaceae	*Isolepis hookeriana*				
Cyperaceae	*Isolepis* sp.	Club-rush			
Cyperaceae	*Lepidosperma laterale*	Variable Sword-sedge			X
Cyperaceae	* *Schoenoplectus erectus*				
Cyperaceae	*Schoenus ericetorum*	Heath Bog-rush			X
Cyperaceae	*Schoenus kennyi*				
Cyperaceae	*Schoenus latelaminatus*	Medusa bog sedge			
Cyperaceae	*Schoenus moorei*				X
Cyperaceae	*Schoenus* sp.				
Hypoxidaceae	*Hypoxis hygrometrica*	Golden Star, Golden Weather-glass			
Iridaceae	*Patersonia sericea*	Native Iris, Silky Purple-flag			
Iridaceae	*Patersonia* sp.	Purple-flag			
Juncaceae	*Juncus aridicola*	Tussock Rush			
Juncaceae	* *Juncus bufonius*	Toad Rush			
Juncaceae	*Juncus flavidus*				
Juncaceae	*Juncus ochrocoleus*				
Juncaceae	*Juncus psammophilus*				
Juncaceae	*Juncus radula*	Hoary Rush			
Juncaceae	*Juncus remotiflorus*				
Juncaceae	*Juncus* sp.	Rush			
Juncaceae	*Juncus subsecundus*				
Lomandraceae	*Lomandra confertifolia*				
Lomandraceae	*Lomandra confertifolia* subsp. *pallida*				
Lomandraceae	*Lomandra filiformis* subsp. *filiformis*	Wattle Mat-rush			
Lomandraceae	*Lomandra leucocephala* subsp. *leucocephala*	Woolly-head Mat-rush			X
Lomandraceae	*Lomandra longifolia*	Spiny-headed Mat-rush, Honey Reed			
Lomandraceae	*Lomandra multiflora*	Many-flowered Mat-rush			X
Lomandraceae	*Lomandra multiflora* (terete form)	Many-flowered Mat-rush			
Lomandraceae	*Lomandra* sp.				
Orchidaceae	(Orchidaceae genus unknown)	Unidentified Orchid			
Orchidaceae	*Caladenia fuscata*	Dusky Fingers			X
Orchidaceae	*Calochilus campestris*	Copper Beard-orchid			X
Orchidaceae	*Calochilus robertsonii*	Purplish Beard-orchid			X
Orchidaceae	*Calochilus* sp.	Beard Orchid			
Orchidaceae	*Cyanicula caerulea*	Blue Fairy, Blue Caladenia			

Family	Species	Common name	TSC Act Status	EPBC Act Status	Meander
Orchidaceae	Cymbidium canaliculatum				
Orchidaceae	Diuris goonooensis	Western Donkey Orchid			X
Orchidaceae	Diuris tricolor		V		X
Orchidaceae	Microtis unifolia	Onion Orchid			X
Orchidaceae	Paracaleana minor	Small Duck Orchid			X
Orchidaceae	Pterostylis boormanii				X
Orchidaceae	Pterostylis cobarensis		V		X
Orchidaceae	Pterostylis lingua	Large-tongue Rustyhood			
Orchidaceae	Pterostylis mitchellii	Mitchell's Rustyhood			X
Orchidaceae	Pterostylis mutica	Midget Greenhood			X
Orchidaceae	Pterostylis praetermissa				X
Orchidaceae	Pterostylis setifera				X
Orchidaceae	Pterostylis setifera X boormanii				X
Orchidaceae	Pterostylis sp.	Greenhood Orchid			
Orchidaceae	Pterostylis sp. aff chaetophorus				X
Orchidaceae	Pterostylis sp. aff mitchellii				X
Orchidaceae	Pterostylis sp. aff praetermissa				X
Orchidaceae	Pterostylis woollsii	Long-tail Greenhood			X
Phormiaceae	Dianella longifolia	Smooth Flax-lily			
Phormiaceae	Dianella porracea	Inland Flax-lily			
Phormiaceae	Dianella revoluta	Blue Flax-lily, Spreading Flax-lily			X
Phormiaceae	Dianella sp.				
Phormiaceae	Stypandra glauca	Nodding Blue-Lily			
Poaceae	(Poaceae genus unknown)				
Poaceae	* Aira sp.				
Poaceae	Ancistrachne uncinulata	Hooked-hairy panic Grass			
Poaceae	Aristida acuta				
Poaceae	Aristida calycina	Dark Wiregrass			
Poaceae	Aristida caput-medusae	Many-headed Wiregrass			
Poaceae	Aristida contorta	Bunched Kerosene Grass			
Poaceae	Aristida echinata				
Poaceae	Aristida holathera var. holathera				
Poaceae	Aristida jerichoensis	Jericho Wiregrass			
Poaceae	Aristida jerichoensis var. jerichoensis	Jericho Wiregrass			X
Poaceae	Aristida jerichoensis var. subspinulifera	Jericho Wire-grass			
Poaceae	Aristida leichhardtiana				
Poaceae	Aristida obscura	Rough-seed Wire-grass			
Poaceae	Aristida personata				
Poaceae	Aristida psammophila				
Poaceae	Aristida queenslandica var. queenslandica				
Poaceae	Aristida ramosa	Purple Wiregrass			
Poaceae	Aristida sp.	Wiregrass			
Poaceae	Aristida vagans	Threeawn Speargrass			
Poaceae	Aristida warburgii	Wiregrass			
Poaceae	Arundinella nepalensis	Reedgrass			
Poaceae	Austrodanthonia bipartita	Wallaby Grass			
Poaceae	Austrodanthonia caespitosa	RInged Wallaby Grass			
Poaceae	Austrodanthonia eriantha	Hill Wallaby Grass			
Poaceae	Austrodanthonia monticola	Wallaby Grass			
Poaceae	Austrodanthonia penicillata	Slender Wallaby Grass			
Poaceae	Austrodanthonia racemosa	Wallaby Grass			
Poaceae	Austrodanthonia sp.	Wallaby Grass			
Poaceae	Austrostipa pubescens	Speargrass			
Poaceae	Austrostipa rudis	Speargrass			
Poaceae	Austrostipa scabra subsp. scabra	Rough Speargrass, Corkscrew Grass			
Poaceae	Austrostipa setacea	Corkscrew Grass			
Poaceae	Austrostipa sp.	Speargrass			
Poaceae	Austrostipa verticillata	Slender Bamboo Grass			
Poaceae	* Avena ludoviciana	Ludo Wild Oats			
Poaceae	* Avena sativa	Oats			
Poaceae	Bothriochloa decipiens	Redleg Grass, Pitted Bluegrass			X
Poaceae	Bothriochloa ewartiana	Desert Bluegrass			
Poaceae	Bothriochloa sp.				
Poaceae	* Briza sp.				
Poaceae	* Bromus brevis				
Poaceae	* Bromus catharticus	Prairie Grass			
Poaceae	* Cenchrus incertus	Spiny Burrgrass			
Poaceae	Chloris divaricata	Slender Chloris, Small Chloris			
Poaceae	* Chloris gayana	Rhodes Grass			
Poaceae	Chloris sp.	Rhodes Grass			
Poaceae	Chloris truncata	Windmill Grass			
Poaceae	Chloris ventricosa	Tall Windmill Grass			
Poaceae	Cleistochloa rigida				X
Poaceae	Cymbopogon obtectus	Silky-heads			
Poaceae	Cymbopogon refractus	Barbed Wire Grass			X
Poaceae	* Cynodon dactylon	Couch, Bermuda Grass			
Poaceae	* Dactylis glomerata	Cocksfoot, Cocksfoot Grass			
Poaceae	Dactyloctenium radulans	Button Grass, Finger Grass			X
Poaceae	Deyeuxia sp.				
Poaceae	Dichanthium sericeum	Silky Blue-grass			
Poaceae	Dichanthium sp.				
Poaceae	Dichelachne micrantha	Shorthair Plumegrass			
Poaceae	Dichelachne sp.	Plume Grass			
Poaceae	Digitaria ammophila	Silky Umbrella Grass			X
Poaceae	Digitaria breviglumis				X
Poaceae	Digitaria brownii	Cotton Panic Grass			
Poaceae	Digitaria diffusa				X
Poaceae	Digitaria divaricatissima	Umbrella Grass			
Poaceae	Digitaria ramularis				
Poaceae	* Digitaria sanguinalis	A Summer Grass, Crab Grass			
Poaceae	Digitaria sp.				
Poaceae	Diplachne fusca	Brown Beetle Grass			
Poaceae	Echinochloa colona	Awnless Barnyard Grass			
Poaceae	* Echinochloa crus-galli	Barnyard Grass			
Poaceae	Echinopogon caespitosus	Tufted Hedgehog Grass			
Poaceae	Echinopogon ovatus	Forest Hedgehog Grass			
Poaceae	Elymus scaber	Rough Wheatgrass			
Poaceae	Enneapogon avenaceus	Bottle Washers			
Poaceae	Enneapogon sp.				
Poaceae	Enteropogon acicularis	Curly Windmill Grass			
Poaceae	Entolasia stricta	Wiry Panic			
Poaceae	Eragrostis alveiformis				
Poaceae	Eragrostis brownii	Brown's Lovegrass			
Poaceae	* Eragrostis curvula	African Lovegrass			
Poaceae	Eragrostis elongata	Clustered Lovegrass			
Poaceae	Eragrostis lacunaria	Purple Lovegrass			
Poaceae	Eragrostis leptostachya	Paddock Lovegrass			
Poaceae	Eragrostis parviflora	Weeping Lovegrass			X
Poaceae	Eragrostis sororia				
Poaceae	Eragrostis sp.	Love Grass			
Poaceae	Eragrostis speciosa				
Poaceae	Eriachne mucronata	Mountain Wanderrie Grass			
Poaceae	Eriochloa crebra	Cup Grass			
Poaceae	Eriochloa pseudoacrotricha	Early Spring Grass			
Poaceae	Eulalia aurea	Silky Browntop			
Poaceae	* Hyparrhenia hirta	Coolatai Grass			
Poaceae	Imperata cylindrica	Blady Grass			
Poaceae	Lachnagrostis filiformis				
Poaceae	Leptochloa divaricatissima				
Poaceae	* Lolium perenne	Perennial Ryegrass			
Poaceae	* Lolium sp.	Ryegrass			
Poaceae	* Melinis repens	Red Natal Grass			
Poaceae	Microlaena stipoides	Meadow Rice-grass, Weeping Grass			X
Poaceae	Panicum buncei				
Poaceae	Panicum decompositum	Native Millet			
Poaceae	Panicum effusum	Hairy Panic			
Poaceae	* Panicum maximum	Guinea Grass			
Poaceae	Panicum simile	Two-colour Panic			
Poaceae	Panicum sp.				
Poaceae	Paspalidium caespitosum	Brigalow Grass			
Poaceae	Paspalidium constrictum	Knottybutt Grass			
Poaceae	Paspalidium criniforme	Paspalidium			
Poaceae	Paspalidium gracile	Slender Panic			
Poaceae	Paspalidium jubiflorum	Warrego Grass			
Poaceae	Paspalidium sp.				
Poaceae	* Paspalum dilatatum	Paspalum			
Poaceae	Paspalum sp.				
Poaceae	Perotis rara	Comet Grass			
Poaceae	* Phalaris paradoxa	Paradoxa Grass			
Poaceae	Phragmites australis	Common Reed			
Poaceae	* Polypogon monspeliensis	Annual Beardgrass, Rabbit-foot Grass			
Poaceae	Pseudoraphis spinescens	Spiny Mudgrass			
Poaceae	Rytidosperma bipartitum				
Poaceae	Rytidosperma racemosum var. obtusatum				
Poaceae	Rytidosperma setaceum	Small-flowered Wallaby Grass			
Poaceae	Rytidosperma setaceum	Small-flowered Wallaby Grass			
Poaceae	Rytidosperma sp.				
Poaceae	Schizachyrium fragile				
Poaceae	* Setaria parviflora	Slender Pigeon Grass			
Poaceae	* Setaria sp. (unidentified)				
Poaceae	* Sporobolus africanus	Parramatta Grass			
Poaceae	Sporobolus caroli	Fairy Grass			
Poaceae	Sporobolus creber	Slender Rat's-tail Grass			
Poaceae	Sporobolus mitchellii	Rat's-tail Couch			
Poaceae	Sporobolus sp. (unidentified)				
Poaceae	Themeda australis	Kangaroo Grass			
Poaceae	Themeda australis	Kangaroo Grass			
Poaceae	Themeda avenacea	Native Oatgrass			
Poaceae	Thyridolepis mitchelliana	Mulga Grass			
Poaceae	Tragus australianus	Small Burrgrass			
Poaceae	Triodia mitchellii var. breviloba	Porcupine Grass, Buck Spinifex			
Poaceae	Tripogon loliiformis	Five-minute Grass			
Poaceae	Urochloa foliosa	Leafy Panic			
Poaceae	* Vulpia muralis	Rats-tail Fescue			
Poaceae	* Vulpia sp. (unidentified)	Rats-tail Fescue			
Poaceae	Walwhalleya proluta	Rigid Panic			
Poaceae	Walwhalleya subxerophila	Gilgai Grass			
Typhaceae	Typha orientalis	Broad-leaf Cumbungi, Bulrush			
Typhaceae	Typha sp. (unidentified)				
Xanthorrhoeaceae	Xanthorrhoea acaulis				X
Xanthorrhoeaceae	Xanthorrhoea johnsonii	Northern Grass-tree			
Xanthorrhoeaceae	Xanthorrhoea sp.				
Xyridaceae	Xyris complanata	Hatpins			
Xyridaceae	Xyris sp. (unidentified)				

Appendix C: Fauna species list

Taxonomic group	Family	Scientific name	Common name	TSC Act	EPBC Act	Exotic (*)
Amphibia	Myobatrachidae	*Crinia parinsignifera*	Eastern Sign-bearing Froglet	P		
Amphibia	Myobatrachidae	*Crinia signifera*	Common Eastern Froglet	P		
Amphibia	Myobatrachidae	*Crinia sp.*		NA		
Amphibia	Hylidae	*Cyclorana alboguttata*	Striped Burrowing Frog	P		
Amphibia	Hylidae	*Cyclorana platycephala*	Water-holding Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes dumerilii*	Eastern Banjo Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes fletcheri*	Long-thumbed Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Brown-striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes salmini*	Salmon Striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes tasmaniensis*	Spotted Grass Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes terraereginae*	Northern Banjo Frog	P		
Amphibia	Hylidae	*Litoria caerulea*	Green Tree Frog	P		
Amphibia	Hylidae	*Litoria latopalmata*	Broad-palmed Frog	P		
Amphibia	Hylidae	*Litoria peronii*	Peron's Tree Frog	P		
Amphibia	Hylidae	*Litoria rubella*	Desert Tree Frog	P		
Amphibia	Myobatrachidae	*Notaden bennettii*	Crucifix Frog	P		
Amphibia	Myobatrachidae	*Platyplectrum ornatum*	Ornate Burrowing Frog	P		
Amphibia	Myobatrachidae	*Uperoleia rugosa*	Wrinkled Toadlet	P		
Aves	Cacatuidae		Cockatoo sp.	NA		
Aves	Columbidae		Lorikeet sp.	NA		
Aves	Meliphagidae		Honeyeater sp.	NA		
Aves	Podicipedidae		Grebe sp.	NA		
Aves	Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater	P		
Aves	Acanthizidae	*Acanthiza apicalis*	Inland Thornbill	P		
Aves	Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza lineata*	Striated Thornbill	P		
Aves	Acanthizidae	*Acanthiza nana*	Yellow Thornbill	P		
Aves	Acanthizidae	*Acanthiza pusilla*	Brown Thornbill	P		
Aves	Acanthizidae	*Acanthiza reguloides*	Buff-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza sp.*	Unidentified Thornbill	P		
Aves	Acanthizidae	*Acanthiza uropygialis*	Chestnut-rumped Thornbill	P		
Aves	Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	P		
Aves	Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	P		
Aves	Accipitridae	*Accipiter fasciatus*	Brown Goshawk	P		
Aves	Acrocephalidae	*Acrocephalus australis*	Australian Reed-Warbler	P		
Aves	Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	P		
Aves	Psittacidae	*Alisterus scapularis*	Australian King-Parrot	P		
Aves	Anatidae	*Anas gracilis*	Grey Teal	P		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aves	Psittacidae	*Northiella haematogaster*	Blue Bonnet	P		
Aves	Ardeidae	*Nycticorax caledonicus*	Nankeen Night Heron	P		
Aves	Cacatuidae	*Nymphicus hollandicus*	Cockatiel	P		
Aves	Columbidae	*Ocyphaps lophotes*	Crested Pigeon	P		
Aves	Pachycephalidae	*Oreoica gutturalis*	Crested Bellbird	P		
Aves	Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	P		
Aves	Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	P		
Aves	Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	P		
Aves	Megapodiidae	*Pachycephala sp.*	Whistler sp.	NA		
Aves	Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	P		
Aves	Pardalotidae	*Pardalotus striatus*	Striated Pardalote	P		
Aves	Passeridae	*Passer domesticus*	House Sparrow	U		*
Aves	Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican	P		
Aves	Hirundinidae	*Petrochelidon ariel*	Fairy Martin	P		
Aves	Petroicidae	*Petroica goodenovii*	Red-capped Robin	P		
Aves	Petroicidae	*Petroica rosea*	Rose Robin	P		
Aves	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax varius*	Pied Cormorant	P		
Aves	Columbidae	*Phaps chalcoptera*	Common Bronzewing	P		
Aves	Columbidae	*Phaps elegans*	Brush Bronzewing	P		
Aves	Meliphagidae	*Philemon citreogularis*	Little Friarbird	P		
Aves	Meliphagidae	*Philemon corniculatus*	Noisy Friarbird	P		
Aves	Threskiornithidae	*Platalea flavipes*	Yellow-billed Spoonbill	P		
Aves	Threskiornithidae	*Platalea regia*	Royal Spoonbill	P		
Aves	Psittacidae	*Platycercus adscitus*	Pale-headed Rosella	P		
Aves	Psittacidae	*Platycercus elegans*	Crimson Rosella	P		
Aves	Psittacidae	*Platycercus eximius*	Eastern Rosella	P		
Aves	Meliphagidae	*Plectorhyncha lanceolata*	Striped Honeyeater	P		
Aves	Podargidae	*Podargus strigoides*	Tawny Frogmouth	P		
Aves	Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe	P		
Aves	Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	P		
Aves	Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler (eastern subspecies)	V		
Aves	Rallidae	*Porphyrio porphyrio*	Purple Swamphen	P		
Aves	Psittacidae	*Psephotus haematonotus*	Red-rumped Parrot	P		
Aves	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Spotted Bowerbird	P		
Aves	Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	P		
Aves	Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	P		
Aves	Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo	P		
Aves	Acanthizidae	*Smicrornis brevirostris*	Weebill	P		
Aves	Estrildidae	*Stagonopleura guttata*	Diamond Firetail	V		
Aves	Artamidae	*Strepera graculina*	Pied Currawong	P		
Aves	Columbidae	*Streptopelia chinensis*	Spotted Turtle-Dove	U		*
Aves	Corcoracidae	*Struthidea cinerea*	Apostlebird	P		
Aves	Sturnidae	*Sturnus tristis*	Common Myna	U		*
Aves	Sturnidae	*Sturnus vulgaris*	Common Starling	U		*
Aves	Meliphagidae	*Sugomel niger*	Black Honeyeater	P		
Aves	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe	P		
Aves	Estrildidae	*Taeniopygia bichenovii*	Double-barred Finch	P		
Aves	Estrildidae	*Taeniopygia guttata*	Zebra Finch	P		
Aves	Threskiornithidae	*Threskiornis molucca*	Australian White Ibis	P		
Aves	Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis	P		
Aves	Alcedinidae	*Todiramphus sanctus*	Sacred Kingfisher	P		
Aves	Turdidae	*Turdus merula*	Eurasian Blackbird	U		*
Aves	Turnicidae	*Turnix varius*	Painted Button-quail	P		
Aves	Tytonidae	*Tyto alba*	Barn Owl	P		
Aves	Tytonidae	*Tyto novaehollandiae*	Masked Owl	V		
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing	P		
Aves	Charadriidae	*Vanellus miles novaehollandiae*	Spur-winged Plover	P		
Aves	Charadriidae	*Vanellus tricolor*	Banded Lapwing	P		
Aves	Timaliidae	*Zosterops lateralis*	Silvereye	P		
Mammalia	Macropodidae		Wallaby sp.	NA		
Mammalia	Muridae		Mouse sp.	NA		
Mammalia	Muridae		Rat sp.	NA		
Mammalia	Vombatidae		Wombat sp.	NA		
Mammalia	Dasyuridae	*Antechinus flavipes*	Yellow-footed Antechinus	P		
Mammalia	Bovidae	*Bos taurus*	Cow	U		*
Mammalia	Canidae	*Canis lupus*	Dingo	U		*/
Mammalia	Canidae	*Canis lupus familiaris*	Dog	U		*
Mammalia	Bovidae	*Capra hircus*	Goat	U		*
Mammalia	Burramyidae	*Cercartetus nanus*	Eastern Pygmy-possum	V		
Mammalia	Vespertilionidae	*Chalinolobus dwyeri*	Large-eared Pied Bat	V	V	
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus picatus*	Little Pied Bat	V		
Mammalia	Equidae	*Equus sp.*	Horse	U		*
Mammalia	Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	V		
Mammalia	Felidae	*Felis catus*	Cat	U		*
Mammalia	Leporidae	*Lepus capensis*	Hare	U		*
Mammalia	Macropodidae	*Macropus dorsalis*	Black-striped Wallaby	E1		
Mammalia	Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	P		
Mammalia	Macropodidae	*Macropus robustus*	Common Wallaroo	P		
Mammalia	Macropodidae	*Macropus rufogriseus*	Red-necked Wallaby	P		
Mammalia	Macropodidae	*Macropus rufus*	Red Kangaroo	P		
Mammalia	Macropodidae	*Macropus sp.*	kangaroo / wallaby	NA		
Mammalia	Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing Bat	V		
Mammalia	Molossidae	*Mormopterus "Species 3" (little penis)*		P		
Mammalia	Molossidae	*Mormopterus "Species 4" (big penis)*		P		
Mammalia	Molossidae	*Mormopterus planiceps (long penis form)*	Southern Freetail Bat	P		
Mammalia	Molossidae	*Mormopterus sp.*		NA		
Mammalia	Muridae	*Mus musculus*	House Mouse	U		*
Mammalia	Vespertilionidae	*Nyctophilus corbeni*	Corben's Long-eared Bat	V	V	
Mammalia	Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus sp.*	long-eared bat	NA		
Mammalia	Leporidae	*Oryctolagus cuniculus*	Rabbit	U		*
Mammalia	Bovidae	*Ovis aries*	Sheep (feral)	U		*
Mammalia	Petauridae	*Petaurus breviceps*	Sugar Glider	P		
Mammalia	Petauridae	*Petaurus norfolcensis*	Squirrel Glider	V		
Mammalia	Petauridae	*Petaurus spp.*		NA		
Mammalia	Phascolarctidae	*Phascolarctos cinereus*	Koala	V	V	
Mammalia	Muridae	*Pseudomys pilligaensis*	Pilliga Mouse	V	V	
Mammalia	Pteropodidae	*Pteropus sp.*	Flying-fox sp.	NA		
Mammalia	Muridae	*Rattus rattus*	Black Rat	U		*
Mammalia	Muridae	*Rattus spp.*		NA		
Mammalia	Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat	P		
Mammalia	Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	V		
Mammalia	Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat	V		
Mammalia	Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens greyii*	Little Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens sp.*	Unidentified broad-nosed bat	NA		
Mammalia	Suidae	*Sus scrofa*	Pig	U		*
Mammalia	Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	P		
Mammalia	Molossidae	*Tadarida australis*	White-striped Freetail-bat	P		
Mammalia	Phalangeridae	*Trichosurus vulpecula*	Brushtail Possum	P		
Mammalia	Vespertilionidae	*Vespadelus sp.*		NA		
Mammalia	Vespertilionidae	*Vespadelus troughtoni*	Eastern Cave Bat	V		
Mammalia	Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat	P		
Mammalia	Vombatidae	*Vombatus ursinus*	Common Wombat	P		
Mammalia	Canidae	*Vulpes vulpes*	Fox	U		*
Mammalia	Macropodidae	*Wallabia bicolor*	Swamp Wallaby	P		
Reptilia			Turtle sp.	NA		
Reptilia	Gekkonidae		Gecko sp.	NA		
Reptilia	Agamidae	*Amphibolurus muricatus*	Jacky Lizard	P		
Reptilia	Agamidae	*Amphibolurus nobbi*	Nobbi	P		
Reptilia	Elapidae	*Brachyurophis australis*	Coral Snake	P		
Reptilia	Scincidae	*Carlia sp.*		NA		
Reptilia	Scincidae	*Carlia tetradactyla*	Southern Rainbow-skink	P		
Reptilia	Chelidae	*Chelodina longicollis*	Snake-necked Turtle	P		
Reptilia	Scincidae	*Cryptoblepharus australis*	Inland Snake-eyed Skink	P		
Reptilia	Scincidae	*Cryptoblepharus pannosus*	Ragged snake-eyed skink	P		
Reptilia	Scincidae	*Cryptoblepharus sp.*		NA		
Reptilia	Scincidae	*Cryptoblepharus virgatus*	Cream-striped Shinning-skink	P		
Reptilia	Scincidae	*Ctenotus allotropis*	Brown-blazed Wedgesnout Ctenotus	P		
Reptilia	Scincidae	*Ctenotus robustus*	Robust Ctenotus	P		
Reptilia	Elapidae	*Demansia psammophis*	Yellow-faced Whip Snake	P		
Reptilia	Elapidae	*Denisonia devisi*	De Vis' Banded Snake	P		
Reptilia	Gekkonidae	*Diplodactylus vittatus*	Wood Gecko	P		
Reptilia	Scincidae	*Egernia striolata*	Tree Skink	P		
Reptilia	Elapidae	*Furina diadema*	Red-naped Snake	P		
Reptilia	Gekkonidae	*Gehyra dubia*	Dubious Dtella	P		
Reptilia	Gekkonidae	*Gehyra sp.*	Unidentified Dtella	P		
Reptilia	Gekkonidae	*Gehyra variegata*	Tree Dtella	P		
Reptilia	Scincidae	*Hemiergis decresiensis*	Three-toed Earless Skink	P		
Reptilia	Gekkonidae	*Heteronotia binoei*	Bynoe's Gecko	P		
Reptilia	Elapidae	*Hoplocephalus bitorquatus*	Pale-headed Snake	V		
Reptilia	Scincidae	*Lampropholis guichenoti*	Pale-flecked Garden Sunskink	P		
Reptilia	Scincidae	*Lampropholis sp.*		NA		
Reptilia	Scincidae	*Lerista bougainvillii*	South-eastern Slider	P		
Reptilia	Scincidae	*Lerista punctatovittata*	Eastern Robust Slider	P		
Reptilia	Scincidae	*Lerista sp.*		NA		
Reptilia	Pygopodidae	*Lialis burtonis*	Burton's Snake-lizard	P		
Reptilia	Scincidae	*Lygisaurus foliorum*	Tree-base Litter-skink	P		
Reptilia	Scincidae	*Menetia greyii*	Common Dwarf Skink	P		
Reptilia	Boidae	*Morelia spilota metcalfei*	Murray/Darling Carpet Python	P		
Reptilia	Scincidae	*Morethia boulengeri*	South-eastern Morethia Skink	P		
Reptilia	Scincidae	*Morethia sp.*		NA		
Reptilia	Gekkonidae	*Oedura sp.*		NA		
Reptilia	Agamidae	*Pogona barbata*	Bearded Dragon	P		
Reptilia	Elapidae	*Pseudechis australis*	King Brown Snake	P		
Reptilia	Elapidae	*Pseudechis guttatus*	Blue-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudonaja textilis*	Eastern Brown Snake	P		
Reptilia	Gekkonidae	*Strophurus intermedius*	Southern Spiny-tailed Gecko	P		
Reptilia	Gekkonidae	*Strophurus sp.*		NA		
Reptilia	Gekkonidae	*Strophurus williamsi*	Eastern Spiny-tailed Gecko	P		
Reptilia	Elapidae	*Suta suta*	Curl Snake	P		
Reptilia	Scincidae	*Tiliqua scincoides*	Eastern Blue-tongue	P		
Reptilia	Agamidae	*Tympanocryptis sp.*		NA		
Reptilia	Agamidae	*Tympanocryptis tetraporophora*	Eyrean Earless Dragon	P		
Reptilia	Varanidae	*Varanus gouldii*	Gould's Goanna	P		
Reptilia	Varanidae	*Varanus sp.*	Unidentified Goanna	NA		
Reptilia	Varanidae	*Varanus varius*	Lace Monitor	P		
Reptilia	Elapidae	*Vermicella annulata*	Bandy-bandy	P		
Reptilia	Scincidae		Skink sp.	NA		

Taxonomic group	Family	Scientific name	Common name	TSC Act	EPBC Act	Exotic (*)
Amphibia	Myobatrachidae	*Crinia parinsignifera*	Eastern Sign-bearing Froglet	P		
Amphibia	Myobatrachidae	*Crinia signifera*	Common Eastern Froglet	P		
Amphibia	Myobatrachidae	*Crinia sp.*		NA		
Amphibia	Hylidae	*Cyclorana alboguttata*	Striped Burrowing Frog	P		
Amphibia	Hylidae	*Cyclorana platycephala*	Water-holding Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes dumerilii*	Eastern Banjo Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes fletcheri*	Long-thumbed Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Brown-striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes salmini*	Salmon Striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes tasmaniensis*	Spotted Grass Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes terraereginae*	Northern Banjo Frog	P		
Amphibia	Hylidae	*Litoria caerulea*	Green Tree Frog	P		
Amphibia	Hylidae	*Litoria latopalmata*	Broad-palmed Frog	P		
Amphibia	Hylidae	*Litoria peronii*	Peron's Tree Frog	P		
Amphibia	Hylidae	*Litoria rubella*	Desert Tree Frog	P		
Amphibia	Myobatrachidae	*Notaden bennettii*	Crucifix Frog	P		
Amphibia	Myobatrachidae	*Platyplectrum ornatum*	Ornate Burrowing Frog	P		
Amphibia	Myobatrachidae	*Uperoleia rugosa*	Wrinkled Toadlet	P		
Aves	Cacatuidae		Cockatoo sp.	NA		
Aves	Columbidae		Lorikeet sp.	NA		
Aves	Meliphagidae		Honeyeater sp.	NA		
Aves	Podicipedidae		Grebe sp.	NA		
Aves	Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater	P		
Aves	Acanthizidae	*Acanthiza apicalis*	Inland Thornbill	P		
Aves	Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza lineata*	Striated Thornbill	P		
Aves	Acanthizidae	*Acanthiza nana*	Yellow Thornbill	P		
Aves	Acanthizidae	*Acanthiza pusilla*	Brown Thornbill	P		
Aves	Acanthizidae	*Acanthiza reguloides*	Buff-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza sp.*	Unidentified Thornbill	P		
Aves	Acanthizidae	*Acanthiza uropygialis*	Chestnut-rumped Thornbill	P		
Aves	Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	P		
Aves	Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	P		
Aves	Accipitridae	*Accipiter fasciatus*	Brown Goshawk	P		
Aves	Acrocephalidae	*Acrocephalus australis*	Australian Reed-Warbler	P		
Aves	Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	P		
Aves	Psittacidae	*Alisterus scapularis*	Australian King-Parrot	P		
Aves	Anatidae	*Anas gracilis*	Grey Teal	P		
Aves	Anatidae	*Anas superciliosa*	Pacific Black Duck	P		
Aves	Anhingidae	*Anhinga novaehollandiae*	Australasian Darter	P		
Aves	Meliphagidae	*Anthochaera carunculata*	Red Wattlebird	P		
Aves	Motacillidae	*Anthus novaeseelandiae*	Australian Pipit	P		
Aves	Acanthizidae	*Aphelocephala leucopsis*	Southern Whiteface	P		
Aves	Psittacidae	*Aprosmictus erythropterus*	Red-winged Parrot	P		
Aves	Apodidae	*Apus pacificus*	Fork-tailed Swift	P	M	
Aves	Accipitridae	*Aquila audax*	Wedge-tailed Eagle	P		
Aves	Ardeidae	*Ardea modesta*	Eastern Great Egret	P	M	
Aves	Ardeidae	*Ardea pacifica*	White-necked Heron	P		
Aves	Artamidae	*Artamus cinereus*	Black-faced Woodswallow	P		
Aves	Artamidae	*Artamus cyanopterus*	Dusky Woodswallow	V		
Aves	Artamidae	*Artamus leucorynchus*	White-breasted Woodswallow	P		
Aves	Artamidae	*Artamus minor*	Little Woodswallow	P		
Aves	Artamidae	*Artamus personatus*	Masked Woodswallow	P		
Aves	Artamidae	*Artamus superciliosus*	White-browed Woodswallow	P		
Aves	Anatidae	*Aythya australis*	Hardhead	P		
Aves	Psittacidae	*Barnardius zonarius*	Australian Ringneck	P		
Aves	Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo	P		
Aves	Cacatuidae	*Cacatua sanguinea*	Little Corella	P		
Aves	Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	P		
Aves	Cacatuidae	*Calyptorhynchus funereus*	Yellow-tailed Black-Cockatoo	P		
Aves	Cacatuidae	*Calyptorhynchus lathami*	Glossy Black-Cockatoo	V		
Aves	Alcedinidae	*Ceyx azureus*	Azure Kingfisher	P		
Aves	Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo	P		
Aves	Cuculidae	*Chalcites lucidus*	Shining Bronze-Cuckoo	P		
Aves	Anatidae	*Chenonetta jubata*	Australian Wood Duck	P		
Aves	Acanthizidae	*Chthonicola sagittata*	Speckled Warbler	V		
Aves	Megaluridae	*Cincloramphus mathewsi*	Rufous Songlark	P		
Aves	Psophodidae	*Cinclosoma punctatum*	Spotted Quail-thrush	P		
Aves	Accipitridae	*Circus assimilis*	Spotted Harrier	V		
Aves	Climacteridae	*Climacteris picumnus victoriae*	Brown Treecreeper (eastern subspecies)	P		
Aves	Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	P		
Aves	Campephagidae	*Coracina maxima*	Ground Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina papuensis*	White-bellied Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina tenuirostris*	Cicadabird	P		
Aves	Corcoracidae	*Corcorax melanorhamphos*	White-winged Chough	P		
Aves	Climacteridae	*Cormobates leucophaea*	White-throated Treecreeper	P		
Aves	Corvidae	*Corvus bennetti*	Little Crow	P		
Aves	Corvidae	*Corvus coronoides*	Australian Raven	P		
Aves	Corvidae	*Corvus mellori*	Little Raven	P		
Aves	Corvidae	*Corvus sp.*	Crow	P		
Aves	Artamidae	*Cracticus nigrogularis*	Pied Butcherbird	P		
Aves	Artamidae	*Cracticus tibicen*	Australian Magpie	P		
Aves	Artamidae	*Cracticus torquatus*	Grey Butcherbird	P		
Aves	Alcedinidae	*Dacelo novaeguineae*	Laughing Kookaburra	P		
Aves	Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	V		
Aves	Anatidae	*Dendrocygna eytoni*	Plumed Whistling-Duck	P		
Aves	Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird	P		
Aves	Casuariidae	*Dromaius novaehollandiae*	Emu	P		
Aves	Ardeidae	*Egretta novaehollandiae*	White-faced Heron	P		
Aves	Accipitridae	*Elanus axillaris*	Black-shouldered Kite	P		
Aves	Charadriidae	*Elseyornis melanops*	Black-fronted Dotterel	P		
Aves	Meliphagidae	*Entomyzon cyanotis*	Blue-faced Honeyeater	P		
Aves	Cacatuidae	*Eolophus roseicapillus*	Galah	P		
Aves	Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	P		
Aves	Cuculidae	*Eudynamys orientalis*	Eastern Koel	P		
Aves	Caprimulgidae	*Eurostopodus mystacalis*	White-throated Nightjar	P		
Aves	Coraciidae	*Eurystomus orientalis*	Dollarbird	P		
Aves	Falconidae	*Falco berigora*	Brown Falcon	P		
Aves	Falconidae	*Falco cenchroides*	Nankeen Kestrel	P		
Aves	Falconidae	*Falco longipennis*	Australian Hobby	P		
Aves	Falconidae	*Falco peregrinus*	Peregrine Falcon	P		
Aves	Falconidae	*Falco subniger*	Black Falcon	V		
Aves	Pachycephalidae	*Falcunculus frontatus*	Crested Shrike-tit	P		
Aves	Rallidae	*Fulica atra*	Eurasian Coot	P		
Aves	Rallidae	*Gallinula tenebrosa*	Dusky Moorhen	P		
Aves	Columbidae	*Geopelia cuneata*	Diamond Dove	P		
Aves	Columbidae	*Geopelia humeralis*	Bar-shouldered Dove	P		
Aves	Columbidae	*Geopelia striata*	Peaceful Dove	P		
Aves	Acanthizidae	*Gerygone fusca*	Western Gerygone	P		
Aves	Acanthizidae	*Gerygone olivacea*	White-throated Gerygone	P		
Aves	Psittacidae	*Glossopsitta concinna*	Musk Lorikeet	P		
Aves	Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	V		
Aves	Monarchidae	*Grallina cyanoleuca*	Magpie-lark	P		
Aves	Meliphagidae	*Grantiella picta*	Painted Honeyeater	V	V	
Aves	Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-eagle	P	Ma	
Aves	Accipitridae	*Haliastur sphenurus*	Whistling Kite	P		
Aves	Accipitridae	*Hieraaetus morphnoides*	Little Eagle	V		
Aves	Apodidae	*Hirundapus caudacutus*	White-throated Needletail	P	M	
Aves	Hirundinidae	*Hirundo neoxena*	Welcome Swallow	P		
Aves	Campephagidae	*Lalage sueurii*	White-winged Triller	P		
Aves	Meliphagidae	*Lichenostomus chrysops*	Yellow-faced Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus leucotis*	White-eared Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus melanops*	Yellow-tufted Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus penicillatus*	White-plumed Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater	P		
Aves	Meliphagidae	*Lichmera indistincta*	Brown Honeyeater	P		
Aves	Accipitridae	*Lophoictinia isura*	Square-tailed Kite	V		
Aves	Columbidae	*Lopholaimus antarcticus*	Topknot Pigeon	P		
Aves	Maluridae	*Malurus cyaneus*	Superb Fairy-wren	P		
Aves	Maluridae	*Malurus lamberti*	Variegated Fairy-wren	P		
Aves	Maluridae	*Malurus sp.*	Unidentified Fairy-wren	NA		
Aves	Meliphagidae	*Manorina flavigula*	Yellow-throated Miner	P		
Aves	Meliphagidae	*Manorina melanocephala*	Noisy Miner	P		
Aves	Petroicidae	*Melanodryas cucullata cucullata*	Hooded Robin (south-eastern form)	V		
Aves	Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater	P		
Aves	Meliphagidae	*Melithreptus brevirostris*	Brown-headed Honeyeater	P		
Aves	Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater	P		
Aves	Psittacidae	*Melopsittacus undulatus*	Budgerigar	P		
Aves	Meropidae	*Merops ornatus*	Rainbow Bee-eater	P	M	
Aves	Phalacrocoracidae	*Microcarbo melanoleucos*	Little Pied Cormorant	P		
Aves	Petroicidae	*Microeca fascinans*	Jacky Winter	P		
Aves	Accipitridae	*Milvus migrans*	Black Kite	P		
Aves	Monarchidae	*Myiagra cyanoleuca*	Satin Flycatcher	P	M, Mar	
Aves	Monarchidae	*Myiagra inquieta*	Restless Flycatcher	P		
Aves	Monarchidae	*Myiagra rubecula*	Leaden Flycatcher	P		
Aves	Estrildidae	*Neochmia modesta*	Plum-headed Finch	P		
Aves	Estrildidae	*Neochmia temporalis*	Red-browed Finch	P		
Aves	Psittacidae	*Neophema pulchella*	Turquoise Parrot	V		
Aves	Strigidae	*Ninox connivens*	Barking Owl	V		
Aves	Strigidae	*Ninox novaeseelandiae*	Southern Boobook	P		
Aves	Psittacidae	*Northiella haematogaster*	Blue Bonnet	P		
Aves	Ardeidae	*Nycticorax caledonicus*	Nankeen Night Heron	P		
Aves	Cacatuidae	*Nymphicus hollandicus*	Cockatiel	P		
Aves	Columbidae	*Ocyphaps lophotes*	Crested Pigeon	P		
Aves	Pachycephalidae	*Oreoica gutturalis*	Crested Bellbird	P		
Aves	Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	P		
Aves	Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	P		
Aves	Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	P		
Aves	Megapodiidae	*Pachycephala sp.*	Whistler sp.	NA		
Aves	Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	P		
Aves	Pardalotidae	*Pardalotus striatus*	Striated Pardalote	P		
Aves	Passeridae	*Passer domesticus*	House Sparrow	U		*
Aves	Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican	P		
Aves	Hirundinidae	*Petrochelidon ariel*	Fairy Martin	P		
Aves	Petroicidae	*Petroica goodenovii*	Red-capped Robin	P		
Aves	Petroicidae	*Petroica rosea*	Rose Robin	P		
Aves	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax varius*	Pied Cormorant	P		
Aves	Columbidae	*Phaps chalcoptera*	Common Bronzewing	P		
Aves	Columbidae	*Phaps elegans*	Brush Bronzewing	P		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Aves	Meliphagidae	*Plectorhyncha lanceolata*	Striped Honeyeater	P		
Aves	Podargidae	*Podargus strigoides*	Tawny Frogmouth	P		
Aves	Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe	P		
Aves	Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	P		
Aves	Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler (eastern subspecies)	V		
Aves	Rallidae	*Porphyrio porphyrio*	Purple Swamphen	P		
Aves	Psittacidae	*Psephotus haematonotus*	Red-rumped Parrot	P		
Aves	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Spotted Bowerbird	P		
Aves	Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	P		
Aves	Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	P		
Aves	Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo	P		
Aves	Acanthizidae	*Smicrornis brevirostris*	Weebill	P		
Aves	Estrildidae	*Stagonopleura guttata*	Diamond Firetail	V		
Aves	Artamidae	*Strepera graculina*	Pied Currawong	P		
Aves	Columbidae	*Streptopelia chinensis*	Spotted Turtle-Dove	U		*
Aves	Corcoracidae	*Struthidea cinerea*	Apostlebird	P		
Aves	Sturnidae	*Sturnus tristis*	Common Myna	U		*
Aves	Sturnidae	*Sturnus vulgaris*	Common Starling	U		*
Aves	Meliphagidae	*Sugomel niger*	Black Honeyeater	P		
Aves	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe	P		
Aves	Estrildidae	*Taeniopygia bichenovii*	Double-barred Finch	P		
Aves	Estrildidae	*Taeniopygia guttata*	Zebra Finch	P		
Aves	Threskiornithidae	*Threskiornis molucca*	Australian White Ibis	P		
Aves	Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis	P		
Aves	Alcedinidae	*Todiramphus sanctus*	Sacred Kingfisher	P		
Aves	Turdidae	*Turdus merula*	Eurasian Blackbird	U		*
Aves	Turnicidae	*Turnix varius*	Painted Button-quail	P		
Aves	Tytonidae	*Tyto alba*	Barn Owl	P		
Aves	Tytonidae	*Tyto novaehollandiae*	Masked Owl	V		
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing	P		
Aves	Charadriidae	*Vanellus miles novaehollandiae*	Spur-winged Plover	P		
Aves	Charadriidae	*Vanellus tricolor*	Banded Lapwing	P		
Aves	Timaliidae	*Zosterops lateralis*	Silvereye	P		
Mammalia	Macropodidae		Wallaby sp.	NA		
Mammalia	Muridae		Mouse sp.	NA		
Mammalia	Muridae		Rat sp.	NA		
Mammalia	Vombatidae		Wombat sp.	NA		
Mammalia	Dasyuridae	*Antechinus flavipes*	Yellow-footed Antechinus	P		
Mammalia	Bovidae	*Bos taurus*	Cow	U		*
Mammalia	Canidae	*Canis lupus*	Dingo	U		*/
Mammalia	Canidae	*Canis lupus familiaris*	Dog	U		*
Mammalia	Bovidae	*Capra hircus*	Goat	U		*
Mammalia	Burramyidae	*Cercartetus nanus*	Eastern Pygmy-possum	V		
Mammalia	Vespertilionidae	*Chalinolobus dwyeri*	Large-eared Pied Bat	V	V	
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus picatus*	Little Pied Bat	V		
Mammalia	Equidae	*Equus sp.*	Horse	U		*
Mammalia	Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	V		
Mammalia	Felidae	*Felis catus*	Cat	U		*
Mammalia	Leporidae	*Lepus capensis*	Hare	U		*
Mammalia	Macropodidae	*Macropus dorsalis*	Black-striped Wallaby	E1		
Mammalia	Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	P		
Mammalia	Macropodidae	*Macropus robustus*	Common Wallaroo	P		
Mammalia	Macropodidae	*Macropus rufogriseus*	Red-necked Wallaby	P		
Mammalia	Macropodidae	*Macropus rufus*	Red Kangaroo	P		
Mammalia	Macropodidae	*Macropus sp.*	kangaroo / wallaby	NA		
Mammalia	Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing Bat	V		
Mammalia	Molossidae	*Mormopterus "Species 3" (little penis)*		P		
Mammalia	Molossidae	*Mormopterus "Species 4" (big penis)*		P		
Mammalia	Molossidae	*Mormopterus planiceps (long penis form)*	Southern Freetail Bat	P		
Mammalia	Molossidae	*Mormopterus sp.*		NA		
Mammalia	Muridae	*Mus musculus*	House Mouse	U		*
Mammalia	Vespertilionidae	*Nyctophilus corbeni*	Corben's Long-eared Bat	V	V	
Mammalia	Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus sp.*	long-eared bat	NA		
Mammalia	Leporidae	*Oryctolagus cuniculus*	Rabbit	U		*
Mammalia	Bovidae	*Ovis aries*	Sheep (feral)	U		*
Mammalia	Petauridae	*Petaurus breviceps*	Sugar Glider	P		
Mammalia	Petauridae	*Petaurus norfolcensis*	Squirrel Glider	V		
Mammalia	Petauridae	*Petaurus spp.*		NA		
Mammalia	Phascolarctidae	*Phascolarctos cinereus*	Koala	V	V	
Mammalia	Muridae	*Pseudomys pilligaensis*	Pilliga Mouse	V	V	
Mammalia	Pteropodidae	*Pteropus sp.*	Flying-fox sp.	NA		
Mammalia	Muridae	*Rattus rattus*	Black Rat	U		*
Mammalia	Muridae	*Rattus spp.*		NA		
Mammalia	Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat	P		
Mammalia	Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	V		
Mammalia	Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat	V		
Mammalia	Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens greyii*	Little Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens sp.*	Unidentified broad-nosed bat	NA		
Mammalia	Suidae	*Sus scrofa*	Pig	U		*
Mammalia	Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	P		
Mammalia	Molossidae	*Tadarida australis*	White-striped Freetail-bat	P		
Mammalia	Phalangeridae	*Trichosurus vulpecula*	Brushtail Possum	P		
Mammalia	Vespertilionidae	*Vespadelus sp.*		NA		
Mammalia	Vespertilionidae	*Vespadelus troughtoni*	Eastern Cave Bat	V		
Mammalia	Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat	P		
Mammalia	Vombatidae	*Vombatus ursinus*	Common Wombat	P		
Mammalia	Canidae	*Vulpes vulpes*	Fox	U		*
Mammalia	Macropodidae	*Wallabia bicolor*	Swamp Wallaby	P		
Reptilia			Turtle sp.	NA		
Reptilia	Gekkonidae		Gecko sp.	NA		
Reptilia	Agamidae	*Amphibolurus muricatus*	Jacky Lizard	P		
Reptilia	Agamidae	*Amphibolurus nobbi*	Nobbi	P		
Reptilia	Elapidae	*Brachyurophis australis*	Coral Snake	P		
Reptilia	Scincidae	*Carlia sp.*		NA		
Reptilia	Scincidae	*Carlia tetradactyla*	Southern Rainbow-skink	P		
Reptilia	Chelidae	*Chelodina longicollis*	Snake-necked Turtle	P		
Reptilia	Scincidae	*Cryptoblepharus australis*	Inland Snake-eyed Skink	P		
Reptilia	Scincidae	*Cryptoblepharus pannosus*	Ragged snake-eyed skink	P		
Reptilia	Scincidae	*Cryptoblepharus sp.*		NA		
Reptilia	Scincidae	*Cryptoblepharus virgatus*	Cream-striped Shinning-skink	P		
Reptilia	Scincidae	*Ctenotus allotropis*	Brown-blazed Wedgesnout Ctenotus	P		
Reptilia	Scincidae	*Ctenotus robustus*	Robust Ctenotus	P		
Reptilia	Elapidae	*Demansia psammophis*	Yellow-faced Whip Snake	P		
Reptilia	Elapidae	*Denisonia devisi*	De Vis' Banded Snake	P		
Reptilia	Gekkonidae	*Diplodactylus vittatus*	Wood Gecko	P		
Reptilia	Scincidae	*Egernia striolata*	Tree Skink	P		
Reptilia	Elapidae	*Furina diadema*	Red-naped Snake	P		
Reptilia	Gekkonidae	*Gehyra dubia*	Dubious Dtella	P		
Reptilia	Gekkonidae	*Gehyra sp.*	Unidentified Dtella	P		
Reptilia	Gekkonidae	*Gehyra variegata*	Tree Dtella	P		
Reptilia	Scincidae	*Hemiergis decresiensis*	Three-toed Earless Skink	P		
Reptilia	Gekkonidae	*Heteronotia binoei*	Bynoe's Gecko	P		
Reptilia	Elapidae	*Hoplocephalus bitorquatus*	Pale-headed Snake	V		
Reptilia	Scincidae	*Lampropholis guichenoti*	Pale-flecked Garden Sunskink	P		
Reptilia	Scincidae	*Lampropholis sp.*		NA		
Reptilia	Scincidae	*Lerista bougainvillii*	South-eastern Slider	P		
Reptilia	Scincidae	*Lerista punctatovittata*	Eastern Robust Slider	P		
Reptilia	Scincidae	*Lerista sp.*		NA		
Reptilia	Pygopodidae	*Lialis burtonis*	Burton's Snake-lizard	P		
Reptilia	Scincidae	*Lygisaurus foliorum*	Tree-base Litter-skink	P		
Reptilia	Scincidae	*Menetia greyii*	Common Dwarf Skink	P		
Reptilia	Boidae	*Morelia spilota metcalfei*	Murray/Darling Carpet Python	P		
Reptilia	Scincidae	*Morethia boulengeri*	South-eastern Morethia Skink	P		
Reptilia	Scincidae	*Morethia sp.*		NA		
Reptilia	Gekkonidae	*Oedura sp.*		NA		
Reptilia	Agamidae	*Pogona barbata*	Bearded Dragon	P		
Reptilia	Elapidae	*Pseudechis australis*	King Brown Snake	P		
Reptilia	Elapidae	*Pseudechis guttatus*	Blue-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudonaja textilis*	Eastern Brown Snake	P		
Reptilia	Gekkonidae	*Strophurus intermedius*	Southern Spiny-tailed Gecko	P		
Reptilia	Gekkonidae	*Strophurus sp.*		NA		
Reptilia	Gekkonidae	*Strophurus williamsi*	Eastern Spiny-tailed Gecko	P		
Reptilia	Elapidae	*Suta suta*	Curl Snake	P		
Reptilia	Scincidae	*Tiliqua scincoides*	Eastern Blue-tongue	P		
Reptilia	Agamidae	*Tympanocryptis sp.*		NA		
Reptilia	Agamidae	*Tympanocryptis tetraporophora*	Eyrean Earless Dragon	P		
Reptilia	Varanidae	*Varanus gouldii*	Gould's Goanna	P		
Reptilia	Varanidae	*Varanus sp.*	Unidentified Goanna	NA		
Reptilia	Varanidae	*Varanus varius*	Lace Monitor	P		
Reptilia	Elapidae	*Vermicella annulata*	Bandy-bandy	P		
Reptilia	Scincidae		Skink sp.	NA		

Taxonomic group	Family	Scientific name	Common name	TSC Act	EPBC Act	Exotic (*)
Amphibia	Myobatrachidae	*Crinia parinsignifera*	Eastern Sign-bearing Froglet	P		
Amphibia	Myobatrachidae	*Crinia signifera*	Common Eastern Froglet	P		
Amphibia	Myobatrachidae	*Crinia sp.*		NA		
Amphibia	Hylidae	*Cyclorana alboguttata*	Striped Burrowing Frog	P		
Amphibia	Hylidae	*Cyclorana platycephala*	Water-holding Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes dumerilii*	Eastern Banjo Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes fletcheri*	Long-thumbed Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes peronii*	Brown-striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes salmini*	Salmon Striped Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes tasmaniensis*	Spotted Grass Frog	P		
Amphibia	Myobatrachidae	*Limnodynastes terraereginae*	Northern Banjo Frog	P		
Amphibia	Hylidae	*Litoria caerulea*	Green Tree Frog	P		
Amphibia	Hylidae	*Litoria latopalmata*	Broad-palmed Frog	P		
Amphibia	Hylidae	*Litoria peronii*	Peron's Tree Frog	P		
Amphibia	Hylidae	*Litoria rubella*	Desert Tree Frog	P		
Amphibia	Myobatrachidae	*Notaden bennettii*	Crucifix Frog	P		
Amphibia	Myobatrachidae	*Platyplectrum ornatum*	Ornate Burrowing Frog	P		
Amphibia	Myobatrachidae	*Uperoleia rugosa*	Wrinkled Toadlet	P		
Aves	Cacatuidae		Cockatoo sp.	NA		
Aves	Columbidae		Lorikeet sp.	NA		
Aves	Meliphagidae		Honeyeater sp.	NA		
Aves	Podicipedidae		Grebe sp.	NA		
Aves	Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater	P		
Aves	Acanthizidae	*Acanthiza apicalis*	Inland Thornbill	P		
Aves	Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza lineata*	Striated Thornbill	P		
Aves	Acanthizidae	*Acanthiza nana*	Yellow Thornbill	P		
Aves	Acanthizidae	*Acanthiza pusilla*	Brown Thornbill	P		
Aves	Acanthizidae	*Acanthiza reguloides*	Buff-rumped Thornbill	P		
Aves	Acanthizidae	*Acanthiza sp.*	Unidentified Thornbill	P		
Aves	Acanthizidae	*Acanthiza uropygialis*	Chestnut-rumped Thornbill	P		
Aves	Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	P		
Aves	Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	P		
Aves	Accipitridae	*Accipiter fasciatus*	Brown Goshawk	P		
Aves	Acrocephalidae	*Acrocephalus australis*	Australian Reed-Warbler	P		
Aves	Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	P		
Aves	Psittacidae	*Alisterus scapularis*	Australian King-Parrot	P		
Aves	Anatidae	*Anas gracilis*	Grey Teal	P		
Aves	Anatidae	*Anas superciliosa*	Pacific Black Duck	P		
Aves	Anhingidae	*Anhinga novaehollandiae*	Australasian Darter	P		
Aves	Meliphagidae	*Anthochaera carunculata*	Red Wattlebird	P		
Aves	Motacillidae	*Anthus novaeseelandiae*	Australian Pipit	P		
Aves	Acanthizidae	*Aphelocephala leucopsis*	Southern Whiteface	P		
Aves	Psittacidae	*Aprosmictus erythropterus*	Red-winged Parrot	P		
Aves	Apodidae	*Apus pacificus*	Fork-tailed Swift	P	M	
Aves	Accipitridae	*Aquila audax*	Wedge-tailed Eagle	P		
Aves	Ardeidae	*Ardea modesta*	Eastern Great Egret	P	M	
Aves	Ardeidae	*Ardea pacifica*	White-necked Heron	P		
Aves	Artamidae	*Artamus cinereus*	Black-faced Woodswallow	P		
Aves	Artamidae	*Artamus cyanopterus*	Dusky Woodswallow	V		
Aves	Artamidae	*Artamus leucorynchus*	White-breasted Woodswallow	P		
Aves	Artamidae	*Artamus minor*	Little Woodswallow	P		
Aves	Artamidae	*Artamus personatus*	Masked Woodswallow	P		
Aves	Artamidae	*Artamus superciliosus*	White-browed Woodswallow	P		
Aves	Anatidae	*Aythya australis*	Hardhead	P		
Aves	Psittacidae	*Barnardius zonarius*	Australian Ringneck	P		
Aves	Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo	P		
Aves	Cacatuidae	*Cacatua sanguinea*	Little Corella	P		
Aves	Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	P		
Aves	Cacatuidae	*Calyptorhynchus funereus*	Yellow-tailed Black-Cockatoo	P		
Aves	Cacatuidae	*Calyptorhynchus lathami*	Glossy Black-Cockatoo	V		
Aves	Alcedinidae	*Ceyx azureus*	Azure Kingfisher	P		
Aves	Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo	P		
Aves	Cuculidae	*Chalcites lucidus*	Shining Bronze-Cuckoo	P		
Aves	Anatidae	*Chenonetta jubata*	Australian Wood Duck	P		
Aves	Acanthizidae	*Chthonicola sagittata*	Speckled Warbler	V		
Aves	Megaluridae	*Cincloramphus mathewsi*	Rufous Songlark	P		
Aves	Psophodidae	*Cinclosoma punctatum*	Spotted Quail-thrush	P		
Aves	Accipitridae	*Circus assimilis*	Spotted Harrier	V		
Aves	Climacteridae	*Climacteris picumnus victoriae*	Brown Treecreeper (eastern subspecies)	P		
Aves	Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	P		
Aves	Campephagidae	*Coracina maxima*	Ground Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina papuensis*	White-bellied Cuckoo-shrike	P		
Aves	Campephagidae	*Coracina tenuirostris*	Cicadabird	P		
Aves	Corcoracidae	*Corcorax melanorhamphos*	White-winged Chough	P		
Aves	Climacteridae	*Cormobates leucophaea*	White-throated Treecreeper	P		
Aves	Corvidae	*Corvus bennetti*	Little Crow	P		
Aves	Corvidae	*Corvus coronoides*	Australian Raven	P		
Aves	Corvidae	*Corvus mellori*	Little Raven	P		
Aves	Corvidae	*Corvus sp.*	Crow	P		
Aves	Artamidae	*Cracticus nigrogularis*	Pied Butcherbird	P		
Aves	Artamidae	*Cracticus tibicen*	Australian Magpie	P		
Aves	Artamidae	*Cracticus torquatus*	Grey Butcherbird	P		
Aves	Alcedinidae	*Dacelo novaeguineae*	Laughing Kookaburra	P		
Aves	Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	V		
Aves	Anatidae	*Dendrocygna eytoni*	Plumed Whistling-Duck	P		
Aves	Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird	P		
Aves	Casuariidae	*Dromaius novaehollandiae*	Emu	P		
Aves	Ardeidae	*Egretta novaehollandiae*	White-faced Heron	P		
Aves	Accipitridae	*Elanus axillaris*	Black-shouldered Kite	P		
Aves	Charadriidae	*Elseyornis melanops*	Black-fronted Dotterel	P		
Aves	Meliphagidae	*Entomyzon cyanotis*	Blue-faced Honeyeater	P		
Aves	Cacatuidae	*Eolophus roseicapillus*	Galah	P		
Aves	Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	P		
Aves	Cuculidae	*Eudynamys orientalis*	Eastern Koel	P		
Aves	Caprimulgidae	*Eurostopodus mystacalis*	White-throated Nightjar	P		
Aves	Coraciidae	*Eurystomus orientalis*	Dollarbird	P		
Aves	Falconidae	*Falco berigora*	Brown Falcon	P		
Aves	Falconidae	*Falco cenchroides*	Nankeen Kestrel	P		
Aves	Falconidae	*Falco longipennis*	Australian Hobby	P		
Aves	Falconidae	*Falco peregrinus*	Peregrine Falcon	P		
Aves	Falconidae	*Falco subniger*	Black Falcon	V		
Aves	Pachycephalidae	*Falcunculus frontatus*	Crested Shrike-tit	P		
Aves	Rallidae	*Fulica atra*	Eurasian Coot	P		
Aves	Rallidae	*Gallinula tenebrosa*	Dusky Moorhen	P		
Aves	Columbidae	*Geopelia cuneata*	Diamond Dove	P		
Aves	Columbidae	*Geopelia humeralis*	Bar-shouldered Dove	P		
Aves	Columbidae	*Geopelia striata*	Peaceful Dove	P		
Aves	Acanthizidae	*Gerygone fusca*	Western Gerygone	P		
Aves	Acanthizidae	*Gerygone olivacea*	White-throated Gerygone	P		
Aves	Psittacidae	*Glossopsitta concinna*	Musk Lorikeet	P		
Aves	Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	V		
Aves	Monarchidae	*Grallina cyanoleuca*	Magpie-lark	P		
Aves	Meliphagidae	*Grantiella picta*	Painted Honeyeater	V	V	
Aves	Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-eagle	P	Ma	
Aves	Accipitridae	*Haliastur sphenurus*	Whistling Kite	P		
Aves	Accipitridae	*Hieraaetus morphnoides*	Little Eagle	V		
Aves	Apodidae	*Hirundapus caudacutus*	White-throated Needletail	P	M	
Aves	Hirundinidae	*Hirundo neoxena*	Welcome Swallow	P		
Aves	Campephagidae	*Lalage sueurii*	White-winged Triller	P		
Aves	Meliphagidae	*Lichenostomus chrysops*	Yellow-faced Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus leucotis*	White-eared Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus melanops*	Yellow-tufted Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus penicillatus*	White-plumed Honeyeater	P		
Aves	Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater	P		
Aves	Meliphagidae	*Lichmera indistincta*	Brown Honeyeater	P		
Aves	Accipitridae	*Lophoictinia isura*	Square-tailed Kite	V		
Aves	Columbidae	*Lopholaimus antarcticus*	Topknot Pigeon	P		
Aves	Maluridae	*Malurus cyaneus*	Superb Fairy-wren	P		
Aves	Maluridae	*Malurus lamberti*	Variegated Fairy-wren	P		
Aves	Maluridae	*Malurus sp.*	Unidentified Fairy-wren	NA		
Aves	Meliphagidae	*Manorina flavigula*	Yellow-throated Miner	P		
Aves	Meliphagidae	*Manorina melanocephala*	Noisy Miner	P		
Aves	Petroicidae	*Melanodryas cucullata cucullata*	Hooded Robin (south-eastern form)	V		
Aves	Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater	P		
Aves	Meliphagidae	*Melithreptus brevirostris*	Brown-headed Honeyeater	P		
Aves	Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater	P		
Aves	Psittacidae	*Melopsittacus undulatus*	Budgerigar	P		
Aves	Meropidae	*Merops ornatus*	Rainbow Bee-eater	P	M	
Aves	Phalacrocoracidae	*Microcarbo melanoleucos*	Little Pied Cormorant	P		
Aves	Petroicidae	*Microeca fascinans*	Jacky Winter	P		
Aves	Accipitridae	*Milvus migrans*	Black Kite	P		
Aves	Monarchidae	*Myiagra cyanoleuca*	Satin Flycatcher	P	M, Mar	
Aves	Monarchidae	*Myiagra inquieta*	Restless Flycatcher	P		
Aves	Monarchidae	*Myiagra rubecula*	Leaden Flycatcher	P		
Aves	Estrildidae	*Neochmia modesta*	Plum-headed Finch	P		
Aves	Estrildidae	*Neochmia temporalis*	Red-browed Finch	P		
Aves	Psittacidae	*Neophema pulchella*	Turquoise Parrot	V		
Aves	Strigidae	*Ninox connivens*	Barking Owl	V		
Aves	Strigidae	*Ninox novaeseelandiae*	Southern Boobook	P		
Aves	Psittacidae	*Northiella haematogaster*	Blue Bonnet	P		
Aves	Ardeidae	*Nycticorax caledonicus*	Nankeen Night Heron	P		
Aves	Cacatuidae	*Nymphicus hollandicus*	Cockatiel	P		
Aves	Columbidae	*Ocyphaps lophotes*	Crested Pigeon	P		
Aves	Pachycephalidae	*Oreoica gutturalis*	Crested Bellbird	P		
Aves	Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	P		
Aves	Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	P		
Aves	Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	P		
Aves	Megapodiidae	*Pachycephala sp.*	Whistler sp.	NA		
Aves	Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	P		
Aves	Pardalotidae	*Pardalotus striatus*	Striated Pardalote	P		
Aves	Passeridae	*Passer domesticus*	House Sparrow	U		*
Aves	Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican	P		
Aves	Hirundinidae	*Petrochelidon ariel*	Fairy Martin	P		
Aves	Petroicidae	*Petroica goodenovii*	Red-capped Robin	P		
Aves	Petroicidae	*Petroica rosea*	Rose Robin	P		
Aves	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant	P		
Aves	Phalacrocoracidae	*Phalacrocorax varius*	Pied Cormorant	P		
Aves	Columbidae	*Phaps chalcoptera*	Common Bronzewing	P		
Aves	Columbidae	*Phaps elegans*	Brush Bronzewing	P		
Aves	Meliphagidae	*Philemon citreogularis*	Little Friarbird	P		
Aves	Meliphagidae	*Philemon corniculatus*	Noisy Friarbird	P		
Aves	Threskiornithidae	*Platalea flavipes*	Yellow-billed Spoonbill	P		
Aves	Threskiornithidae	*Platalea regia*	Royal Spoonbill	P		
Aves	Psittacidae	*Platycercus adscitus*	Pale-headed Rosella	P		
Aves	Psittacidae	*Platycercus elegans*	Crimson Rosella	P		
Aves	Psittacidae	*Platycercus eximius*	Eastern Rosella	P		
Aves	Meliphagidae	*Plectorhyncha lanceolata*	Striped Honeyeater	P		
Aves	Podargidae	*Podargus strigoides*	Tawny Frogmouth	P		
Aves	Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe	P		
Aves	Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	P		
Aves	Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler (eastern subspecies)	V		
Aves	Rallidae	*Porphyrio porphyrio*	Purple Swamphen	P		
Aves	Psittacidae	*Psephotus haematonotus*	Red-rumped Parrot	P		
Aves	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Spotted Bowerbird	P		
Aves	Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	P		
Aves	Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	P		
Aves	Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo	P		
Aves	Acanthizidae	*Smicrornis brevirostris*	Weebill	P		
Aves	Estrildidae	*Stagonopleura guttata*	Diamond Firetail	V		
Aves	Artamidae	*Strepera graculina*	Pied Currawong	P		
Aves	Columbidae	*Streptopelia chinensis*	Spotted Turtle-Dove	U		*
Aves	Corcoracidae	*Struthidea cinerea*	Apostlebird	P		
Aves	Sturnidae	*Sturnus tristis*	Common Myna	U		*
Aves	Sturnidae	*Sturnus vulgaris*	Common Starling	U		*
Aves	Meliphagidae	*Sugomel niger*	Black Honeyeater	P		
Aves	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe	P		
Aves	Estrildidae	*Taeniopygia bichenovii*	Double-barred Finch	P		
Aves	Estrildidae	*Taeniopygia guttata*	Zebra Finch	P		
Aves	Threskiornithidae	*Threskiornis molucca*	Australian White Ibis	P		
Aves	Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis	P		
Aves	Alcedinidae	*Todiramphus sanctus*	Sacred Kingfisher	P		
Aves	Turdidae	*Turdus merula*	Eurasian Blackbird	U		*
Aves	Turnicidae	*Turnix varius*	Painted Button-quail	P		
Aves	Tytonidae	*Tyto alba*	Barn Owl	P		
Aves	Tytonidae	*Tyto novaehollandiae*	Masked Owl	V		
Aves	Charadriidae	*Vanellus miles*	Masked Lapwing	P		
Aves	Charadriidae	*Vanellus miles novaehollandiae*	Spur-winged Plover	P		
Aves	Charadriidae	*Vanellus tricolor*	Banded Lapwing	P		
Aves	Timaliidae	*Zosterops lateralis*	Silvereye	P		
Mammalia	Macropodidae		Wallaby sp.	NA		
Mammalia	Muridae		Mouse sp.	NA		
Mammalia	Muridae		Rat sp.	NA		
Mammalia	Vombatidae		Wombat sp.	NA		
Mammalia	Dasyuridae	*Antechinus flavipes*	Yellow-footed Antechinus	P		
Mammalia	Bovidae	*Bos taurus*	Cow	U		*
Mammalia	Canidae	*Canis lupus*	Dingo	U		*/
Mammalia	Canidae	*Canis lupus familiaris*	Dog	U		*
Mammalia	Bovidae	*Capra hircus*	Goat	U		*
Mammalia	Burramyidae	*Cercartetus nanus*	Eastern Pygmy-possum	V		
Mammalia	Vespertilionidae	*Chalinolobus dwyeri*	Large-eared Pied Bat	V	V	
Mammalia	Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat	P		
Mammalia	Vespertilionidae	*Chalinolobus picatus*	Little Pied Bat	V		
Mammalia	Equidae	*Equus sp.*	Horse	U		*
Mammalia	Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	V		
Mammalia	Felidae	*Felis catus*	Cat	U		*
Mammalia	Leporidae	*Lepus capensis*	Hare	U		*
Mammalia	Macropodidae	*Macropus dorsalis*	Black-striped Wallaby	E1		
Mammalia	Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	P		
Mammalia	Macropodidae	*Macropus robustus*	Common Wallaroo	P		
Mammalia	Macropodidae	*Macropus rufogriseus*	Red-necked Wallaby	P		
Mammalia	Macropodidae	*Macropus rufus*	Red Kangaroo	P		
Mammalia	Macropodidae	*Macropus sp.*	kangaroo / wallaby	NA		
Mammalia	Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing Bat	V		
Mammalia	Molossidae	*Mormopterus "Species 3" (little penis)*		P		
Mammalia	Molossidae	*Mormopterus "Species 4" (big penis)*		P		
Mammalia	Molossidae	*Mormopterus planiceps (long penis form)*	Southern Freetail Bat	P		
Mammalia	Molossidae	*Mormopterus sp.*		NA		
Mammalia	Muridae	*Mus musculus*	House Mouse	U		*
Mammalia	Vespertilionidae	*Nyctophilus corbeni*	Corben's Long-eared Bat	V	V	
Mammalia	Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat	P		
Mammalia	Vespertilionidae	*Nyctophilus sp.*	long-eared bat	NA		
Mammalia	Leporidae	*Oryctolagus cuniculus*	Rabbit	U		*
Mammalia	Bovidae	*Ovis aries*	Sheep (feral)	U		*
Mammalia	Petauridae	*Petaurus breviceps*	Sugar Glider	P		
Mammalia	Petauridae	*Petaurus norfolcensis*	Squirrel Glider	V		
Mammalia	Petauridae	*Petaurus spp.*		NA		
Mammalia	Phascolarctidae	*Phascolarctos cinereus*	Koala	V	V	
Mammalia	Muridae	*Pseudomys pilligaensis*	Pilliga Mouse	V	V	
Mammalia	Pteropodidae	*Pteropus sp.*	Flying-fox sp.	NA		
Mammalia	Muridae	*Rattus rattus*	Black Rat	U		*
Mammalia	Muridae	*Rattus spp.*		NA		
Mammalia	Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat	P		
Mammalia	Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	V		
Mammalia	Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat	V		
Mammalia	Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens greyii*	Little Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat	P		
Mammalia	Vespertilionidae	*Scotorepens sp.*	Unidentified broad-nosed bat	NA		
Mammalia	Suidae	*Sus scrofa*	Pig	U		*
Mammalia	Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	P		
Mammalia	Molossidae	*Tadarida australis*	White-striped Freetail-bat	P		
Mammalia	Phalangeridae	*Trichosurus vulpecula*	Brushtail Possum	P		
Mammalia	Vespertilionidae	*Vespadelus sp.*		NA		
Mammalia	Vespertilionidae	*Vespadelus troughtoni*	Eastern Cave Bat	V		
Mammalia	Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat	P		
Mammalia	Vombatidae	*Vombatus ursinus*	Common Wombat	P		
Mammalia	Canidae	*Vulpes vulpes*	Fox	U		*
Mammalia	Macropodidae	*Wallabia bicolor*	Swamp Wallaby	P		
Reptilia			Turtle sp.	NA		
Reptilia	Gekkonidae		Gecko sp.	NA		
Reptilia	Agamidae	*Amphibolurus muricatus*	Jacky Lizard	P		
Reptilia	Agamidae	*Amphibolurus nobbi*	Nobbi	P		
Reptilia	Elapidae	*Brachyurophis australis*	Coral Snake	P		
Reptilia	Scincidae	*Carlia sp.*		NA		
Reptilia	Scincidae	*Carlia tetradactyla*	Southern Rainbow-skink	P		
Reptilia	Chelidae	*Chelodina longicollis*	Snake-necked Turtle	P		
Reptilia	Scincidae	*Cryptoblepharus australis*	Inland Snake-eyed Skink	P		
Reptilia	Scincidae	*Cryptoblepharus pannosus*	Ragged snake-eyed skink	P		
Reptilia	Scincidae	*Cryptoblepharus sp.*		NA		
Reptilia	Scincidae	*Cryptoblepharus virgatus*	Cream-striped Shinning-skink	P		
Reptilia	Scincidae	*Ctenotus allotropis*	Brown-blazed Wedgesnout Ctenotus	P		
Reptilia	Scincidae	*Ctenotus robustus*	Robust Ctenotus	P		
Reptilia	Elapidae	*Demansia psammophis*	Yellow-faced Whip Snake	P		
Reptilia	Elapidae	*Denisonia devisi*	De Vis' Banded Snake	P		
Reptilia	Gekkonidae	*Diplodactylus vittatus*	Wood Gecko	P		
Reptilia	Scincidae	*Egernia striolata*	Tree Skink	P		
Reptilia	Elapidae	*Furina diadema*	Red-naped Snake	P		
Reptilia	Gekkonidae	*Gehyra dubia*	Dubious Dtella	P		
Reptilia	Gekkonidae	*Gehyra sp.*	Unidentified Dtella	P		
Reptilia	Gekkonidae	*Gehyra variegata*	Tree Dtella	P		
Reptilia	Scincidae	*Hemiergis decresiensis*	Three-toed Earless Skink	P		
Reptilia	Gekkonidae	*Heteronotia binoei*	Bynoe's Gecko	P		
Reptilia	Elapidae	*Hoplocephalus bitorquatus*	Pale-headed Snake	V		
Reptilia	Scincidae	*Lampropholis guichenoti*	Pale-flecked Garden Sunskink	P		
Reptilia	Scincidae	*Lampropholis sp.*		NA		
Reptilia	Scincidae	*Lerista bougainvillii*	South-eastern Slider	P		
Reptilia	Scincidae	*Lerista punctatovittata*	Eastern Robust Slider	P		
Reptilia	Scincidae	*Lerista sp.*		NA		
Reptilia	Pygopodidae	*Lialis burtonis*	Burton's Snake-lizard	P		
Reptilia	Scincidae	*Lygisaurus foliorum*	Tree-base Litter-skink	P		
Reptilia	Scincidae	*Menetia greyii*	Common Dwarf Skink	P		
Reptilia	Boidae	*Morelia spilota metcalfei*	Murray/Darling Carpet Python	P		
Reptilia	Scincidae	*Morethia boulengeri*	South-eastern Morethia Skink	P		
Reptilia	Scincidae	*Morethia sp.*		NA		
Reptilia	Gekkonidae	*Oedura sp.*		NA		
Reptilia	Agamidae	*Pogona barbata*	Bearded Dragon	P		
Reptilia	Elapidae	*Pseudechis australis*	King Brown Snake	P		
Reptilia	Elapidae	*Pseudechis guttatus*	Blue-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake	P		
Reptilia	Elapidae	*Pseudonaja textilis*	Eastern Brown Snake	P		
Reptilia	Gekkonidae	*Strophurus intermedius*	Southern Spiny-tailed Gecko	P		
Reptilia	Gekkonidae	*Strophurus sp.*		NA		
Reptilia	Gekkonidae	*Strophurus williamsi*	Eastern Spiny-tailed Gecko	P		
Reptilia	Elapidae	*Suta suta*	Curl Snake	P		
Reptilia	Scincidae	*Tiliqua scincoides*	Eastern Blue-tongue	P		
Reptilia	Agamidae	*Tympanocryptis sp.*		NA		
Reptilia	Agamidae	*Tympanocryptis tetraporophora*	Eyrean Earless Dragon	P		
Reptilia	Varanidae	*Varanus gouldii*	Gould's Goanna	P		
Reptilia	Varanidae	*Varanus sp.*	Unidentified Goanna	NA		
Reptilia	Varanidae	*Varanus varius*	Lace Monitor	P		
Reptilia	Elapidae	*Vermicella annulata*	Bandy-bandy	P		
Reptilia	Scincidae		Skink sp.	NA		

Appendix D: Plant community type profiles

27 Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions

BVT Equivalent ID & Name:	NA219: Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions
Vegetation formation (CMA):	Semi-arid Woodlands (Grassy subformation) [Namoi CMA]
Vegetation class:	Riverine Plain Woodlands
Conservation status:	Endangered EPBC Act/ TSC Act

Photo by John Benson (Benson et al., 2010)

Characteristic Trees	*Acacia pendula, Casuarina cristata, Capparis mitchellii*, *Eucalyptus populnea* subsp. *bimbil*
Shrubs/ Vines/ Epiphytes	Shrubs/Vines/Epiphytes not surveyed
Groundcovers	Groundcover not surveyed
Threatened Flora Species	Not surveyed
Exotic Flora Species	Not surveyed
Vegetation Structure	Open Woodland
% remaining in NSW	14% ±
No. sites sampled	0, all vegetation located on private property not able to be accessed

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
No data available												

35: Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA117: Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Semi-arid Woodlands (Grassy subformation) [Namoi CMA]
Vegetation class:	Brigalow Clay Plain Woodlands
Conservation status:	Endangered EPBC Act/ TSC Act

Characteristic Trees	*Acacia harpophylla* (Brigalow), *Casuarina cristata* (Belah)
Shrubs/ Vines/ Epiphytes	*Rhagodia spinescens* (Spiny Saltbush), *Geijera parviflora* (Wilga), *Maireana microphylla* (Eastern Cottonbush), *Eremophila deserti* (Turkey-bush)
Groundcovers	*Enteropogon acicularis* (Curly Windmill Grass), *Brunoniella australis* (Blue Trumpet), *Sclerolaena tetracuspis* (Brigalow Burr), *Portulaca oleracea* (Pigweed), *Sporobolus caroli* (Fairy Grass)
Threatened Flora Species	*Lepidium aschersonii* (Vulnerable EPBC Act/ TSC Act)
Exotic Flora Species	*Opuntia stricta* (Prickly Pear), *Portulaca pilosa, Cynodon dactylon* (Couch), *Carthamus lanatus* (Saffron Thistle)
Vegetation Structure	Woodland / Open Forest
% remaining in NSW	10% ± 50%
No. sites sampled	25

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
21.52 ±10.15	15.32 ±10.74	6.27 ±9.66	17.68 ±20.18	9.40 ±10.5	10.1 ±19.6	1.8 ±6.2	44.2 ±27.9	19.2 ±22.5	0.6 ±1.5	0.2 ±0.6	54.1 ±63.0	0.8 ±0.4

55: Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions

BVT Equivalent ID & Name:	NA102: Belah woodland on alluvial plains in central-north NSW
Vegetation formation (CMA):	Semi-arid Woodlands (Grassy subformation) [Namoi CMA]
Vegetation class:	Brigalow Clay Plain Woodlands
Conservation status:	Not listed

Characteristic Trees	*Casuarina cristata* (Belah), *Eucalyptus pilligaensis* (Narrow-leaved Grey Box)
Shrubs/ Vines/ Epiphytes	*Geijera parviflora* (Wilga), *Eremophila deserti* (Turkey-bush), *Maireana microphylla* (Eastern Cottonbush), *Exocarpos aphyllus (*Leafless Ballart), *Rhagodia spinescens* (Spiny Saltbush), *Pittosporum angustifolium* (Berrigan)
Groundcovers	*Enteropogon acicularis* (Curly Windmill Grass), *Portulaca oleracea* (Pigweed), *Paspalidium sp., Brunoniella australis* (Blue Trumpet), *Carex inversa* (Knob Sedge)
Threatened Flora Species	-
Exotic Flora Species	*Opuntia stricta* (Prickly Pear), *Oxalis sp., Lepidium africanum* (Common Peppercress)
Vegetation Structure	Woodland/ Open Forest
% remaining in NSW	17% ± 50%
No. sites sampled	8

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
19.63 ±8.52	21.95 ±19.69	5.44 ±7.75	19.75 ±21.07	5.25 ±7.17	9.5 ±12.55	4.75 ±11.21	46 ±34.99	15.75 ±16.88	2.75 ±7.01	0.25 ±0.71	28.06 ±39.41	0.58 ±0.50

78: River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions

BVT Equivalent ID & Name:	NA193: River Red Gum riverine woodlands and forests in the Nandewar and Brigalow Belt South Bioregions
Vegetation formation (CMA):	Forested Wetlands [Namoi CMA]
Vegetation class:	Inland Riverine Forests
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus camaldulensis* (River Red Gum)
Shrubs/ Vines/ Epiphytes	-
Groundcovers	*Paspalidium sp., Paspalidium gracile* (Slender Panic), *Dichanthium sericeum*, (Silky Blue-grass), *Alternanthera denticulata* (Common Joyweed), *Oxalis perennans* (Oxalis)
Threatened Flora Species	-
Exotic Flora Species	*Cynodon dactylon (*Couch), *Conyza bonariensis* (Flaxleaf Fleabane), *Bidens subalternans* (Greater Beggar's Ticks), *Xanthium occidentale* (Noogoora Burr), *Bidens pilosa* (Farmer's Friend)
Vegetation Structure	Tall Woodland/ Tall Open Forest
% remaining in NSW	40% ± 50%
No. sites sampled	6

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
20.83 ±7.63	19.58 ±12.63	0.58 ±1.43	33.33 ±31.92	0 ± 0	2.67 ±3.93	39.87 ±47.43	37.33 ±38.96	6.67 ±13.49	0 ± 0	2.17 ±1.94	24.17 ±34.75	0.61 ±0.49

88: Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA179: Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation) [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Callitris glaucophylla* (White Cypress-pine), *Eucalyptus pilligaensis* (Narrow-leaved Grey Box), *Allocasuarina luehmannii* (Bulloak)
Shrubs/ Vines/ Epiphytes	*Geijera parviflora* (Wilga), *Acacia deanei subsp. Deanei* (Green Wattle)
Groundcovers	*Enteropogon acicularis* (Curly Windmill Grass), *Eragrostis lacunaria* (Purple Lovegrass), *Fimbristylis dichotoma*, *Aristida sp.*, *Aristida caput-medusae* (Many-headed Wiregrass), *Bruniella australis* (Blue Trumpet), *Lomandra multiflora* (Many-flowered Mat-rush), *Paspalidium sp., Carex inversa* (Knob Sedge)
Threatened Flora Species	*Lepidium monoplocoides* (Endangered TSC / EPBC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act), *Tylophora linearis* (Vulnerable TSC Act/ Endangered EPBC Act)
Exotic Flora Species	*Opuntia stricta* (Prickly Pear), *Gomphrena celosioides* (Gomphrena Weed), *Lycium ferocissimum* (African Boxthorn)
Vegetation Structure	Woodland/ Open Woodland
% remaining in NSW	62% ± 80%
No. sites sampled	36

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
25.67 ±9.52	12.61 ±8.96	9.25 ±10.17	29.39 ±18.90	8.67 ±17.18	9.33 ±10.63	0.22 ±1.05	41.38 ±19.06	18.62 ±17.40	0.48 ±1.38	1.28 ±1.45	32.69 ±33.26	0.77 ±0.41

141: Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA121: Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation) [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus crebra* (Narrow-leaved Ironbark)
Shrubs/ Vines/ Epiphytes	*Acacia caroleae, Melaleuca erubescens, Melaleuca uncinata* (Broom Honeymyrtle), *Platysace lanceolata* (Lance-leaf Platysace), *Mirbelia pungens, Calytrix tetragona* (Fringe-myrtle), *Cassytha pubescens* (Devil's Twine), *Hibbertia covenyana, Lissanthe strigosa* (Peach Heath), *Westringia cheelii*
Groundcovers	*Aristida sp.* (Wiregrass), *Dianella revoluta* (Blue Flax-lily), *Hypericum gramineum* (Small St Johns-wort), *Cheilanthes sieberi subsp. Sieberi* (Rock Fern), *Cyperus gracilis* (Slender Sedge), *Digitaria breviglumis, Drosera sp.* (Sundew)*, Goodenia paniculata, Poranthera microphylla* (Small Poranthera)
Threatened Flora Species	*Tylophora linearis* (Vulnerable TSC Act/ Endangered EPBC Act)
Exotic Flora Species	-
Vegetation Structure	Tall Shrubland
% remaining in NSW	89% ± 30%
No. sites sampled	4

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
20.25 ±8.10	9.55 ±11.25	28.13 ±15.02	10.5 ±9.57	62 ±13.95	7 ±6.22	0 ± 0				0 ± 0	0 ± 0	1 ± 0

202: Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA141: Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion
Vegetation formation (CMA):	Grassy Woodlands [Namoi CMA]
Vegetation class:	Western Slopes Grassy Woodlands
Conservation status:	Endangered TSC Act

Characteristic Trees	*Eucalyptus conica* (Fuzzy Box), *Callitris glaucophylla* (White Cypress-pine), *Eucalyptus chloroclada* (Dirty Gum)
Shrubs/ Vines/ Epiphytes	*Acacia deanei subsp. deanei* (Green Wattle), *Hibbertia obtusifolia* (Guinea-flower), *Melichrus urceolatus* (Urn Heath)
Groundcovers	*Cymbopogon refractus* (Barbed Wire Grass), *Aristida caput-medusae* (Many-headed Wiregrass), *Aristida sp.* (Wiregrass) , *Cheilanthes sieberi subsp. Sieberi* (Rock Fern), *Austrostipa verticillata* (Slender Bamboo Grass), *Austrostipa scabra subsp. Scabra* (Rough Speargrass), *Ajuga australis*(Native Bugle), *Dianella revoluta* (Blue Flax-lily)
Threatened Flora Species	*Polygala linariifolia* (Endangered TSC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act)
Exotic Flora Species	*Opuntia aurantiaca* (Tiger Pear), *Bidens subalternans* (Greater Beggar's Ticks), *Conyza bonariensis* (Flaxleaf Fleabane)
Vegetation Structure	Woodland/ Open Forest
% remaining in NSW	25% ± 60%
No. sites sampled	16

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
20.25 ±8.10	9.55 ±11.25	28.13 ±15.02	10.5 ±9.57	62 ±13.95	7 ±6.22	0 ± 0				0 ± 0	0 ± 0	1 ± 0

256: Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion

BVT Equivalent ID & Name:	NA143: Green Mallee scrub on sandstone rises in the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation) [Namoi CMA]
Vegetation class:	North-west Slopes Dry Sclerophyll Woodlands
Conservation status:	Not listed

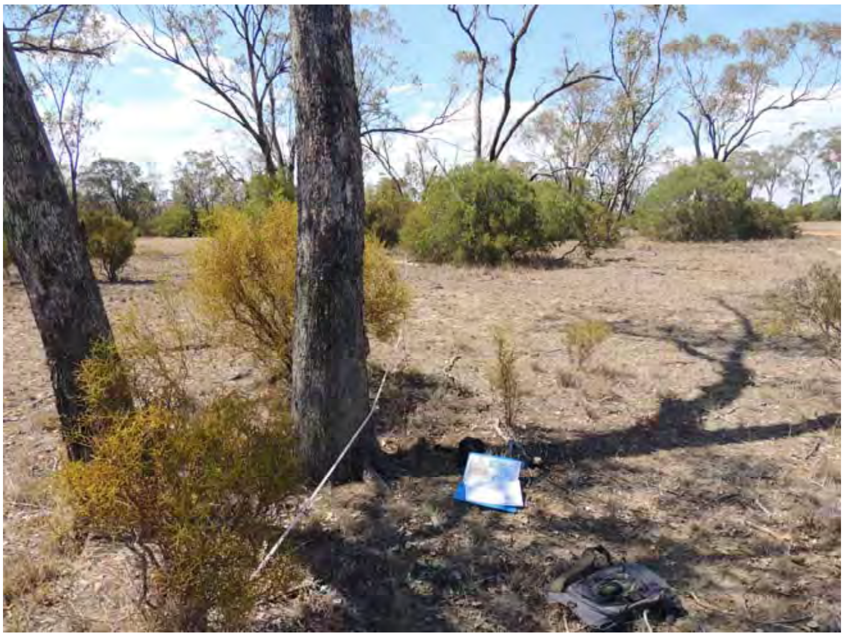
Characteristic Trees	*Eucalyptus viridis* (Green Mallee)
Shrubs/ Vines/ Epiphytes	*Solanum ferocissimum* (Spiny Potato-bush*), Dodonaea viscosa subsp. cuneata* (Wedge-leaf Hopbush), *Psydrax oleifolia* (Wild Lemon), *Solanum jucundum*
Groundcovers	*Aristida caput-medusae(*Many-headed Wiregrass), *Austrostipa scabra subsp. scabra (*Rough Speargrass), *Paspalidium gracile* (Slender Panic), *Cheilanthes sieberi subsp. sieberi* (Rock Fern), *Digitaria sp., Panicum sp.*
Threatened Flora Species	-
Exotic Flora Species	-
Vegetation Structure	Low Woodland/ Low Open Forest
% remaining in NSW	77% ± 50%
No. sites sampled	1

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
31	31.5	3	70	2	6	0	26	0	0	0	0	1

397: Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion

BVT Equivalent ID & Name:	NA179: Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed



Characteristic Trees	*Eucalyptus populnea subsp. bimbil* (Poplar Box), *Callitris glaucophylla* (White Cypress-pine), *Allocasuarina luehmannii* (Bulloak)
Shrubs/ Vines/ Epiphytes	*Geijera parviflora* (Wilga), *Maireana microphylla* (Eastern Cottonbush), *Eremophila deserti* (Turkey-bush)
Groundcovers	*Bothriochloa decipiens* (Redleg Grass), *Eragrostis elongata* (Clustered Lovegrass), *Eragrostis leptostachya* (Paddock Lovegrass), *Carex inversa* (Knob Sedge), *Glycine sp., Aristida sp.*, *Juncus aridicola* (Tussock Rush), *Eragrostis lacunaria* (Purple Lovegrass), *Austrostipa scabra subsp. scabra* (Rough Speargrass), *Fimbristylis dichotoma*
Threatened Flora Species	-
Exotic Flora Species	*Portulaca pilosa, Gomphrena celosioides* (Gomphrena Weed), *Cynodon dactylon* (Couch).
Vegetation Structure	Woodland
% remaining in NSW	80% ± 20%
No. sites sampled	11

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
22.27 ± 8.92	14.79 ± 9.46	4.68 ± 8.78	23.82 ±21.06	0.55 ± 1.81	8.18 ±14.65	1.64 ± 5.43	36.91 ±19.85	29.45 ±15.95	0.36 ± 1.21	1.36 ± 2.25	18.18 ±19.90	0.82 ± 0.40

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 BBS Bioregion

BVT Equivalent ID & Name:	NA227: White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Allocasuarina luehmannii* (Bulloak), *Eucalyptus crebra* (Narrow-leaved Ironbark), *Callitris glaucophylla* (White Cypress-pine)
Shrubs/ Vines/ Epiphytes	*Acacia spectabilis, Cassinia arcuata* (Sifton Bush), *Lissanthe strigosa* (Peach Heath)
Groundcovers	*Fimbristylis dichotoma, Cheilanthes sieberi subsp. sieberi* (Rock Fern), *Lomandra multiflora* (Many-flowered Mat-rush), *Gahnia aspera* (Rough-leaved Saw-sedge), *Dianella revoluta* (Blue Flax-lily), *Eragrostis brownii* (Brown's Lovegrass), *Eragrostis lacunaria* (Purple Lovegrass), *Digitaria breviglumis Goodenia rotundifolia*, *Aristida sp*., *Digitaria diffusa*
Threatened Flora Species	*Diuris tricolor* (Vulnerable TSC Act), *Polygala linariifolia* (Endangered TSC Act), *Pomaderris queenslandica* (Endangered TSC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act), *Tylophora linearis* (Endangered TSC / EPBC Act)
Exotic Flora Species	*Conyza bonariensis* (Flaxleaf Fleabane), *Sonchus oleraceus* (Common Sow-thistle), *Conyza sp., Solanum sp.*
Vegetation Structure	Tall Woodland
% remaining in NSW	73% ± 30%
No. sites sampled	57

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
31.9 ±10.09	8.61 ±7.86	10.68 ±10.05	25.17 ±16.98	14.55 ±19.24	10.8 ±11.10	0.17 ±1.29	52.14 ±28.88	10.31 ±11.85	0.55 ±1.99	0.47 ±0.81	45.2 ±31.19	0.97 ±0.12

399: Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion

BVT Equivalent ID & Name:	NA197: Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion
Vegetation formation (CMA):	Grassy Woodlands [Namoi CMA]
Vegetation class:	New England Grassy Woodlands
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus blakelyi* (Blakely's Red Gum), *Callitris glaucophylla* (White Cypress-pine)
Shrubs/ Vines/ Epiphytes	*Acacia deanei subsp. deanei* (Green Wattle), *Leptospermum polygalifolium subsp. transmontanum* (Tantoon)
Groundcovers	*Lomandra longifolia* (Spiny-headed Mat-rush), *Imperata cylindrica* (Blady Grass), *Arundinella nepalensis* (Reedgrass), *Chrysocephalum apiculatum* (Common Everlasting), *Juncus sp., Austrostipa verticillata* (Slender Bamboo Grass), *Cymbopogon refractus* (Barbed Wire Grass)
Threatened Flora Species	*Pterostylis cobarensis* (Vulnerable TSC / EPBC Act)
Exotic Flora Species	*Cynodon dactylon* (Couch) , *Opuntia stricta* (Prickly Pear), *Bidens subalternans* (Greater Beggar's Ticks)
Vegetation Structure	Woodland
% remaining in NSW	90% ± 50%
No. sites sampled	20

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
23.75 ±7.00	10.14 ±8.78	2.91 ±3.57	24.9 ±23.20	1.7 ±4.01	20 ±12.31	12.3 ±19.50	32.42 ±23.46	19.79 ±17.76	0 ± 0	2.05 ±1.82	26.65 ±18.45	0.75 ±0.44

401: Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region

BVT Equivalent ID & Name:	NA197: Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion
Vegetation formation (CMA):	Grassy Woodlands [Namoi CMA]
Vegetation class:	New England Grassy Woodlands
Conservation status:	Not listed

Characteristic Trees	*Callitris glaucophylla* (White Cypress-pine), *Eucalyptus chloroclada* (Dirty Gum), *Angophora floribunda* (Rough-barked Apple)
Shrubs/ Vines/ Epiphytes	*Acacia deanei subsp. deanei* (Green Wattle), *Melichrus urceolatus* (Urn Heath), *Hibbertia obtusifolia* (Guinea-flower), *Cassinia arcuata* (Sifton Bush)
Groundcovers	*Aristida caput-medusae* (Many-headed Wiregrass), *Cheilanthes sieberi subsp. sieberi* (Rock Fern), *Lomandra multiflora* (Many-flowered Mat-rush), *Microlaena stipoides* (Meadow Rice-grass), *Cymbopogon refractus* (Barbed Wire Grass), *Eragrostis brownii* (Brown's Lovegrass), Dianella *revoluta* (Blue Flax-lily)
Threatened Flora Species	*Diuris tricolor* (Vulnerable TSC Act), *Myriophyllum implicatum* (Critically Endangered TSC Act), *Polygala linariifolia* (Endangered TSC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act)
Exotic Flora Species	*Conyza sp., Sonchus oleraceus* (Common Sow-thistle), *Bidens subalternans* (Greater Beggar's Ticks), *Hypochaeris radicata* (Catsear)
Vegetation Structure	Woodland/ Open Forest
% remaining in NSW	67% ± 50%
No. sites sampled	35

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
33.46 ±11.79	16.03 ± 8.81	8.44 ± 9.45	26.97 ±18.73	7.2 ±12.87	17.66 ±14.31	3.37 ± 8.88	45.06 ±22.26	15.41 ± 21.7	0 ± 0	1.89 ± 1.43	37.6 ±23.41	0.94 ± 0.24

402: Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion

BVT Equivalent ID & Name:	NA160: Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland on Jurassic Sandstone of outwash plains
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	Not listed

Photo by John Benson (Benson et al., 2010)

Characteristic Trees	*Eucalyptus sideroxylon* (Mugga), *Allocasuarina luehmannii* (Bulloak), *Eucalyptus pilligaensis* (Narrow-leaved Grey Box)
Shrubs/ Vines/ Epiphytes	*Myoporum montanum* (Waterbush), *Enchylaena tomentosa* (Ruby Saltbush)
Groundcovers	*Carex inversa* (Knob Sedge), *Juncus sp., Marsilea sp.* (Nardoo), *Cyperus sp., Commelina cyanea* (Blue Spiderwort), *Eragrostis lacunaria* (Purple Lovegrass)
Threatened Flora Species	*Lepidium monoplocoides* (Endangered TSC / EPBC Act)
Exotic Flora Species	*Gomphrena celosioides* (Gomphrena Weed), *Opuntia stricta* (Prickly Pear)
Vegetation Structure	Tall Open Woodland
% remaining in NSW	60% ± 50%
No. sites sampled	2

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
29 ±14.14	7 ±2.83	6.75 ±2.47	28 ±25.46	5 ±7.07	32 ±28.28	2 ±2.83	35 ±4.24	6 ±8.49	1 ±1.41	0.5 ±0.71	27.5 ±27.58	0.5 ±0.71

404: Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests

BVT Equivalent ID & Name:	NA124: Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus fibrosa* (Broad-leaved Red Ironbark), *Corymbia trachyphloia* (Brown Bloodwood), *Callitris glaucophylla* (White Cypress-pine)
Shrubs/ Vines/ Epiphytes	*Cassinia arcuata* (Sifton Bush), *Acacia burrowii* (Burrow's Wattle), *Melichrus urceolatus* (Urn Heath), *Melichrus erubescens*, *Homoranthus flavescens*
Groundcovers	*Cheilanthes sieberi subsp. sieberi* (Rock Fern), *Gahnia aspera* (Rough-leaved Saw-sedge), *Dianella revoluta* (Blue Flax-lily), *Lomandra multiflora* (Many-flowered Mat-rush), *Pomax umbellata* (Pomax), *Aristida sp.*, *Aristida caput-medusae* (Many-headed Wiregrass), *Thyridolepis mitchelliana* (Mulga Grass), *Goodenia rotundifolia*, *Lomandra filiformis subsp. filiformis* (Wattle Mat-rush), *Microlaena stipoides* (Meadow Rice-grass), *Panicum effusum* (Hairy Panic)
Threatened Flora Species	*Bertya opponens* (Vulnerable TSC / EPBC Act), *Polygala linariifolia* (Endangered TSC Act), *Pomaderris queenslandica* (Endangered TSC Act), *Commersonia procumbens* (Vulnerable TSC / EPBC Act), *Tylophora linearis* (Vulnerable TSC Act/ Endangered EPBC Act)
Exotic Flora Species	*Sonchus oleraceus* (Common Sow-thistle), *Conyza sp., Solanum sp.*
Vegetation Structure	Woodland/ Tall Woodland
% remaining in NSW	91% ± 40%
No. sites sampled	34

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
33.97 ±10.06	12.78 ±7.21	12.09 ±7.13	20.47 ±17.67	19 ±17.29	14.06 ±11.49	1.82 ±10.63	47.1 ±21.49	3.7 ±3.20	0 ± 0	1.09 ±1.22	32.93 ±21.62	1 ± 0

405: White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions

BVT Equivalent ID & Name:	NA124: Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	Not listed
Variations	A variation of this community was mapped in the study area (379) which has a canopy dominated by Eucalyptus rossii (Inland Scribbly Gum).

Characteristic Trees	*Corymbia trachyphloia* (White Bloodwood)
Shrubs/ Vines/ Epiphytes	*Melichrus urceolatus* (Urn Heath), *Calytrix tetragona* (Fringe-myrtle), *Brachyloma daphnoides* (Daphne Heath), *Grevillea floribunda* (Rusty Spider-flower), *Allocasuarina diminuta subsp. diminuta*, *Hibbertia obtusifolia* (Guinea-flower), *Persoonia sericea, Boronia glabra, Acacia gladiiformis*, *Cassinia arcuata* (Sifton Bush), *Cassytha pubescens* (Devil's Twine), *Homoranthus flavescens*
Groundcovers	*Pomax umbellata* (Pomax), *Schoenus ericetorum* (Heath Bog-rush), *Lomandra multiflora* (Many-flowered Mat-rush), *Lomandra filiformis subsp. filiformis* (Wattle Mat-rush)
Threatened Flora Species	*Polygala linariifolia* (Endangered TSC Act), *Commersonia procumbens* (Vulnerable TSC / EPBC Act)
Exotic Flora Species	*Conyza sp.*
Vegetation Structure	Woodland
% remaining in NSW	86% ± 30%
No. sites sampled	17

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
39.59 ±8.28	11.08 ±6.03	10.03 ±6.91	7.41 ±9.37	28.59 ±19.59	14.35 ±10.98	0 ± 0	54.86 ±10.19	8.57 ±15.31	0 ± 0	1.12 ±1.11	21.24 ±23.72	1 ± 0

406: White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests

BVT Equivalent ID & Name:	NA124: Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus fibrosa* (Broad-leaved Red Ironbark), *Corymbia trachyphloia* (White Bloodwood), *Acacia cheelii (*Motherumbah)
Shrubs/ Vines/ Epiphytes	*Philotheca ciliata, Dodonaea falcata, Cassinia arcuata* (Sifton Bush), *Grevillea floribunda* (Rusty Spider-flower), *Melichrus erubescens, Calytrix tetragona* (Fringe-myrtle)
Groundcovers	*Pomax umbellata* (Pomax), *Thyridolepis mitchelliana* (Mulga Grass), *Lomandra multiflora* (Many-flowered Mat-rush), *Gahnia aspera* (Rough-leaved Saw-sedge)
Threatened Flora Species	*Bertya opponens* (Vulnerable TSC / EPBC Act), *Pomaderris queenslandica* (Endangered TSC Act), *Commersonia procumbens* (Vulnerable TSC / EPBC Act).
Exotic Flora Species	-
Vegetation Structure	Woodland/ Tall Woodland
% remaining in NSW	94% ± 50%
No. sites sampled	8

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
26.63 ±8.58	15.14 ±5.63	15.11 ±7.21	25.75 ±14.36	10.5 ±6.82	17.5 ±15.63	0 ± 0	49 ±12.38	3 ±3.83	0 ± 0	0.75 ±0.89	45.19 ±30.94	1 ± 0

408: Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region

BVT Equivalent ID & Name:	NA124: Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Eucalyptus chloroclada* (Dirty Gum), *Callitris glaucophylla* (White Cypress-pine), *Callitris endlicheri* (Black Cypress-pine)
Shrubs/ Vines/ Epiphytes	*Bossiaea rhombifolia subsp. concolor, Calytrix tetragona* (Fringe-myrtle), *Grevillea floribunda* (Rusty Spider-flower), *Persoonia sericea*, *Allocasuarina diminuta subsp. diminuta, Melichrus erubescens*
Groundcovers	*Cheilanthes sieberi subsp. sieberi* (Rock Fern), *Brachyloma daphnoides* (Daphne Heath), *Dianella revoluta* (Blue Flax-lily), *Lomandra multiflora* (Many-flowered Mat-rush), *Chrysocephalum apiculatum* (Common Everlasting).
Threatened Flora Species	*Pomaderris queenslandica* (Endangered TSC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act)
Exotic Flora Species	*Solanum sp., Cynodon dactylon* (Couch), *Hypochaeris radicata* (Catsear)
Vegetation Structure	Woodland/ Open Woodland
% remaining in NSW	86% ± 50%
No. sites sampled	9

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
28.22 ±10.23	6.34 ±4.13	5.57 ±4.06	15.56 ±19.41	18 ±16.73	7.78 ±9.61	1.78 ±5.33	56.33 ±25.78	7 ±6.78	3.67 ±8.04	1.56 ±1.33	28.56 ±24.20	0.96 ±0.11

418: White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion

BVT Equivalent ID & Name:	NA179: Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation) [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	*Callitris glaucophylla* (White Cypress-pine), *Eucalyptus melanophloia* (Silver-leaved Ironbark)
Shrubs/ Vines/ Epiphytes	*Geijera parviflora* (Wilga), *Myoporum montanum* (Waterbush), *Rhagodia spinescens* (Spiny Saltbush)
Groundcovers	*Cheilanthes distans* (Bristly Cloak-fern), *Walwhalleya subxerophila* (Gilgai Grass), *Einadia sp., Austrostipa verticillata* (Slender Bamboo Grass), *Austrostipa scabra subsp. scabra* (Rough Speargrass), *Juncus aridicola* (Tussock Rush)
Threatened Flora Species	-
Exotic Flora Species	*Opuntia stricta* (Prickly Pear), *Bidens subalternans* (Greater Beggar's Ticks), *Lepidium bonariense* (Cut-leaf Peppercress)
Vegetation Structure	Woodland/ Open Forest
% remaining in NSW	75% ± 80%
No. sites sampled	7

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
16 ±10.69	17 ±15.83	16.19 ±15.71	32.86 ±26.90	3.43 ±9.07	2.86 ±5.40	23.43 ±40.08	31.71 ±31.44	5.43 ±12.69	0 ± 0	0.29 ±0.49	46.14 ±49.91	0.86 ±0.38

425: Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA121: Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrub/grass subformation) [Namoi CMA]
Vegetation class:	Pilliga Outwash Dry Sclerophyll Forests
Conservation status:	Not listed

Characteristic Trees	-
Shrubs/ Vines/ Epiphytes	*Acacia triptera* (Spurwing Wattle), *Allocasuarina diminuta subsp. diminuta, Calytrix tetragona* (Fringe-myrtle), *Cassinia arcuata* (Sifton Bush), *Homoranthus flavescens, Melaleuca erubescens*, *Melaleuca uncinata* (Broom Honeymyrtle)
Groundcovers	*Aristida sp.*, *Cyperus gracilis* (Slender Sedge), *Digitaria breviglumis, Gahnia aspera* (Rough-leaved Saw-sedge), *Gonocarpus teucrioides* (Raspwort), *Hypericum gramineum* (Small St Johns-wort)
Threatened Flora Species	-
Exotic Flora Species	-
Vegetation Structure	Heathland/ Open Heathland
% remaining in NSW	90% ± 40%
No. sites sampled	2

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
38.5 ±10.61	21.35 ±22.13	9 ±12.73	18 ±16.97	59 ±35.36	23 ±18.38	0 ± 0				0.5 ± 0.71	20.5 ±23.33	1 ± 0

428: Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion

BVT Equivalent ID & Name:	NA126: Carbeen woodland on alluvial soils
Vegetation formation (CMA):	Semi-arid Woodlands (Shrubby subformation) [Namoi CMA]
Vegetation class:	North-west Alluvial Sand Woodlands
Conservation status:	Endangered (TSC Act)

Characteristic Trees	*Callitris glaucophylla* (White Cypress-pine), *Corymbia tessellaris* (Carbeen), *Eucalyptus chloroclada* (Dirty Gum)
Shrubs/ Vines/ Epiphytes	*Geijera parviflora* (Wilga)
Groundcovers	*Austrostipa verticillata* (Slender Bamboo Grass), *Aristida caput-medusae* (Many-headed Wiregrass), *Austrostipa setacea (*Corkscrew Grass), *Microlaena stipoides* (Meadow Rice-grass)
Threatened Flora Species	-
Exotic Flora Species	*Eragrostis curvula* (African Lovegrass), *Bidens subalternans* (Greater Beggar's Ticks), *Opuntia aurantiaca* (Tiger Pear)
Vegetation Structure	Woodland/ Open Woodland
% remaining in NSW	50% ± 60%
No. sites sampled	2

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
22 ±15.56	7.75 ±7.42	12.75 ±3.18	21 ±26.87	1 ±1.41	2 ±2.83	65 ±15.56	13 ±9.90	0 ± 0	0 ± 0	1 ±1.41	49 ±7.07	0.5 ±0.71

40X: White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests

BVT Equivalent ID & Name:	NA124: Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
Vegetation formation (CMA):	Dry Sclerophyll Forests (Shrubby subformation) [Namoi CMA]
Vegetation class:	Western Slopes Dry Sclerophyll Forests
Conservation status:	N/A

Characteristic Trees	*Callitris endlicheri* (Black Cypress-pine), *Eucalyptus chloroclada* (Dirty Gum)
Shrubs/ Vines/ Epiphytes	*Grevillea floribunda* (Rusty Spider-flower), *Calytrix tetragona* (Fringe-myrtle), *Brachyloma daphnoides* (Daphne Heath), *Melichrus urceolatus* (Urn Heath), *Acacia gladiiformis*, *Hibbertia obtusifolia* (Guinea-flower), *Dodonaea peduncularis* (Stalked Hopbush)
Groundcovers	*Lomandra multiflora* (Many-flowered Mat-rush), *Schoenus ericetorum* (Heath Bog-rush), *Aristida sp.*, *Dianella revoluta* (Blue Flax-lily), *Gahnia aspera* (Rough-leaved Saw-sedge)
Threatened Flora Species	*Diuris tricolor* (Vulnerable TSC Act), *Polygala linariifolia* (Endangered TSC Act), *Pterostylis cobarensis* (Vulnerable TSC / EPBC Act), *Tylophora linearis* (Vulnerable TSC Act/ Endangered EPBC Act)
Exotic Flora Species	*Hypochaeris radicata* (Catsear), *Cenchrus incertus* (Spiny Burrgrass), *Oxalis sp.*
Vegetation Structure	Woodland/ Open Woodland
% remaining in NSW	N/A
No. sites sampled	24

Biometric Data:

No. native species	Over-storey cover (%)	Mid-storey cover (%)	Ground cover (grasses)	Ground cover (shrubs)	Ground cover (other)	Exotic plant cover	Litter (%)	Bare/ rock (%)	Cryptogams (%)	No. trees with hollows	Length fallen logs (m)	Over-storey regeneration
31.13 ±8.58	7.5 ±7.17	7.2 ±6.27	16.83 ±20.58	18.78 ±15.73	9.79 ±9.63	0.75 ±2.11	42 ±29.50	14.27 ±13.65	1.33 ±3.18	1.04 ±1.16	41.42 ±40.38	0.96 ±0.20

Appendix E: Fauna habitat type profiles

E1: Water bodies

E2: Closed forest

E3: Grassland

E4: Grassy woodland

E5: Heath

E6: Heathy woodland

E7: Riparian woodland

E8: Shrub grass woodland

E9: Shrubby woodland

E1: Water bodies

Water bodies in the study area mainly consist of dams which are scattered throughout the study area. Some more permanent water holes were found along creek lines and Yarrie Lake is located in the north of the study area (**Figure 19**). Rainfall events such as the flooding event observed in 2010 and the infrequent moderate rainfall during the survey period for this assessment created ephemeral ponding of water in depressions in the landscape. However, due to the sandy soils of much of the study area, the ephemeral water sources were not observed to flow for lengthy periods. The clayey loam soils in the north of the study area were observed to retain ephemeral water ponding for a greater period of time following a rainfall event.

Water holes that retained water during the drier phases provide a range of habitat features including dense aquatic and fringing vegetation, coarse woody debris and foraging resources adjacent to water in dense shrub and canopy. Yarrie Lake and dams provided some degree of habitat, with occasional fringing vegetation and foraging resources (**Plate 14**). However, many of the dams have been cleared surrounding the dam and lack aquatic and fringing vegetation.

The extended dry periods which are characteristic of the Pilliga make water bodies a valuable habitat resource. Water bodies support many fauna, with a range of threatened and migratory water birds, woodland birds, mammals and reptiles considered to potentially use water bodies in the study area (**Appendix A5** and **Plate 13**). It was observed that a greater number of birds were recorded at water bodies in surveys undertaken during extended dry periods, in comparison to surveys undertaken after a rainfall event.


Plate 13: Glossy Black-cockatoo drinking at a water hole; Pale headed Snake at Yarrie Lake

Plate 14: Water hole in creek bed with fringing vegetation; Yarrie Lake; flooded lagoon

E2: Closed forest

There are approximately 2,827 ha of closed forest mapped in the study area. Closed forests are distributed in the northern portion of the study area (**Figure 19**) and characterised by a dense canopy. The midstorey and ground cover is relatively sparse as a result of the dense canopy (**Plate 15**). Hollow abundance is low due to the age of the majority of the trees, however some larger hollows and decorticating bark are present.

Soil substrate of this habitat type is characterised by a clayey loam soils, which allows surface water to remain for a longer duration than the sandy soils found in the majority of the other habitat types. This ephemeral water pooling creates temporary aquatic habitat (**Plate 15**), suitable for breeding amphibians and drinking sources for a range of fauna.

This habitat type was found to support a range of threatened species (**Appendix A5**). In particular, Black-striped Wallaby are known to occur in this habitat type, with numerous previous records and sightings during surveys for this assessment.

Interestingly, two Pale-headed Snake were observed in closed forest patches, one in the Brigalow Nature Reserve and another in a thin strip of roadside closed forest vegetation, which is surrounded by cleared, pasture improved grassland. This is an interesting find as Pale-headed Snakes are thought to favour riparian habitats in drier environments (OEH, 2016b). They also rely on hollow-bearing trees and loose bark (OEH, 2016b) which is not in abundance in this habitat type.

A ultrasonic call of Southern Myotis was previously recorded to a ‘probable’ confidence level in this habitat type (Kendall and Kendall Ecological Consultants, 2007). This species was not recorded during survey for this assessment and there are no records in the BioNet database search undertaken for this assessment (OEH, 2016b). This ‘probable’ recording has not been considered sufficiently supported by additional literature or surveys and as such, Southern Myotis has not been considered a potential species in the study area.

Plate 15: Closed forest; water pooling in closed forest

E3: Grassland

There are approximately 9,465 ha of grassland mapped in the study area. The majority of grasslands are located in the north of the study area (**Figure 19**), as a result of previous clearing of canopy and midstorey structure. There are also small patches of grassland distributed amongst the vegetated areas in the south.

Habitat features of grassland include foraging resources (including seeds, pollen and nectar), mosaics of groundcover density (provides tussocks to protect ground fauna from predators) and logs (**Plate 16**). During rainfall, grasslands in the study area were observed to support ephemeral water bodies.

Grasslands support a range of fauna species, including groundcover and low shrub foraging birds, birds of prey that forage over open habitat and amphibians that breed and forage in flooded grasslands. Threatened fauna recorded in or predicted to use grassland habitat are presented in **Appendix A5** which includes a recent sighting of an Australian Bustard on private property north of the study area.

Plate 16: Grassland; Hooded Robin perching on a log in grassland

E4: Grassy woodland

There are approximately 862 ha of grassy woodland mapped in the study area. Grassy woodland in the study area is predominantly distributed adjacent to riparian habitat along Bohena Creek, with patches also found along Cowallah Creek and Bibblewindi Creek. Other patches of grassy woodland are present in the north of the study area, along roadsides and in paddocks, forming remnant patches in an agricultural landscape (**Figure 19**).

Grassy woodland has a canopy layer of mature eucalypts of up to 30% projected foliage cover. The midstorey is sparse, comprising scattered cypress, shrubs and juvenile eucalypts. The groundcover is dominated by a dense grass layer, with patchy leaf litter, logs and fallen branches and bark. The soil substrate is variable and can consist of loam, sandy loam to light clay soils. The Weeping Myall woodland variation of this habitat type occurs only on cracking clay, black earth or clay loam soils.

Fauna habitat features of grassy woodland include foraging resources (seeds, pollen and nectar), mosaics of groundcover density (provides tussocks to protect ground fauna from predators), canopy and midstorey structure suitable for perching and nesting, hollow-bearing trees, decorticating and fallen bark, logs and fallen branches (**Plate 17**). During rainfall, grassy woodland in the study area can support ephemeral water bodies, although the sandy substrate of this habitat type will require a large amount of rain before the water table is high enough to allow standing water to remain above ground for extended periods of time.

Grassy woodland support a range of fauna species, with threatened woodland birds observed and a range of threatened mammals, birds and reptiles predicted to use this habitat type in the study area (**Appendix A5**). In particular, grassy woodlands are a preferred habitat type for Rufous Bettong. This species was not recorded in the study area but is predicted to occur based on records in the Pilliga and suitable habitat present.


Plate 17: Grassy woodland; Turquoise Parrot perched in grassy woodland

E5: Heath

There are approximately 1,041 ha of heath mapped in the study area. Heath is distributed within the southern forested portion of the study area. The two major patches are a large patch of Broombush dominated heath, west of Bohena Creek and a large patch of Spur-winged Wattle dominated heath in the centre of the study area, north of Yellow Spring Creek (**Plate 18**). Additional small patches of heath are scattered throughout the southern half of the study area (**Figure 19**).

Heath lacks a defined canopy layer with occasional canopy species making up less than five percent projected foliage cover. Heath is characterised by a dense heath layer of approximately one to two metres high and over fifty percent projected foliage cover. The heath layer is dominated by one species (either Broombush or Spur-winged Wattle), with a small percentage of other heath species present in patches. The groundcover is very sparse. The soil substrate is loamy sand over sandy clay or shallow sandy soils which is difficult for burrowing species to penetrate and allows surface water to pool.

Fauna habitat features of heath includes foraging resources (seeds, pollen and nectar) and mosaics of shrub cover density (provides cover to protect ground fauna from predators) (**Plate 18**).

Heath is known or predicted to provide foraging resources for a range of threatened fauna including birds and mammals (**Appendix A5**).In the large Broombush heath patch west of Bohena Creek, scattered *E. sideroxylon* and *E. sideroxylon x E. melliodora* are present in the canopy. These species are known preferred foraging resources for Regent Honeyeater (OEH, 2016b) and this habitat has been categorised as predicted habitat, although no Regent Honeyeater have been recorded in the study area. Pilliga Mouse has previously been recorded in heath, although the clay loam substrate is not considered suitable for it to burrow in.

Plate 18: Broombush dominated heath (top); Spur-wing Wattle dominated heath (bottom)

E6: Heathy woodland

There are approximately 20,604 ha of heathy woodland mapped in the study area. Heathy woodland is one of the most abundant habitat types in the study area (**Figure 19**). The largest continuous patch of heathy woodland is located in the south-eastern corner of the study area. Other large patches are also distributed along creek lines in the southern forested portion of the study area, exterior to riparian habitat.

Heathy woodland has a canopy layer of mature eucalypts of approximately 5% – 20% projected foliage cover. The midstorey is often present in two layers, with one layer approximately two to six metres high and a second layer of approximately 0.5 m to one metre high. The second midstorey is the dense heathy layer and can be present up to approximately 80% projected foliage cover. This layer often comprises of a high diversity of heath species. The groundcover is sparse, comprising grasses, leaf litter, logs and fallen branches and bark. The soil substrate is deep sandy soils.

Fauna habitat features of grassy woodland include foraging resources (seeds, pollen and nectar), mosaics of heath density (provides clumps of low vegetation to protect ground fauna from predators), canopy and midstorey structure suitable for perching and nesting, hollow-bearing trees, decorticating and fallen bark, logs and fallen branches. The sandy soil provides suitable habitat for burrowing (**Plate 19**).

The diverse and dense shrub layer provides a great foraging resource for threatened species (**Appendix A5**) including Pilliga Mouse and Eastern Pygmy Possum. Both of these species have been recorded in this habitat type. During the fluorescent powder tracking of Pilliga Mouse (**Appendix F6**), it was observed that the Pilliga Mouse chose to move through the landscape by following a path underneath the dense shrub patches, actively avoiding open areas in the shrub layer. This would indicate that the dense shrubs provide protection as the Pilliga Mouse is foraging or moving above ground.

Plate 19: Heathy woodland; sandy substrate suitable for Pilliga Mouse burrows

E7: Riparian woodland

There are approximately 7,011 ha of riparian woodland mapped in the study area. Riparian woodlands are distributed along riparian corridors throughout the study area (**Figure 19**). The major riparian corridor in the study area is Bohena Creek, which runs south-north through the centre of the study area and supports continuous linear patches of riparian woodland. Additional riparian corridors in the study area dominated by riparian woodland include Bibblewindi Creek, Spring Creek and Cowallah Creek in the south and Jacks Creek and Bundock Creek in the north.

Riparian woodland has a canopy layer of mature eucalypts of approximately 5% - 30% projected foliage cover. The midstorey is variable, and in some areas can be a shrubby layer dominated by *Leptospermum* spp. approximately two metres high whereas in other areas it comprises cypress and other shrubs between one metre and three metres high. The groundcover is often dense grasses with abundant logs, fallen branches and bark (**Plate 20**).

The majority of the creek beds were dry during surveys for this assessment (except during the flooding in 2010) and provided a flyway or movement corridor for a range terrestrial fauna. Frequent fauna footprints observed in the sandy creek beds included macropods and European fox/cat. Some more permanent waterholes were found and are discussed above in **Section E1**.

Fauna habitat features of riparian woodland also include foraging resources (seeds, pollen and nectar), mosaics of groundcover density (provides tussocks and low shrubs to protect ground fauna from predators), canopy and midstorey structure suitable for perching and nesting, hollow-bearing trees, decorticating and fallen bark, logs and fallen branches.

A range of threatened birds, mammals and reptiles were observed in riparian habitat (**Appendix A5** and **Plate 20**). Riparian habitat provides a suite of preferred feed trees for Koala and hence was the focus of Koala habitat assessments in the study area (**Section 4.7.4** for more details). Koala was not recorded in the study area during survey for this assessment but riparian habitat is considered predicted habitat for Koala (**Appendix A5**).

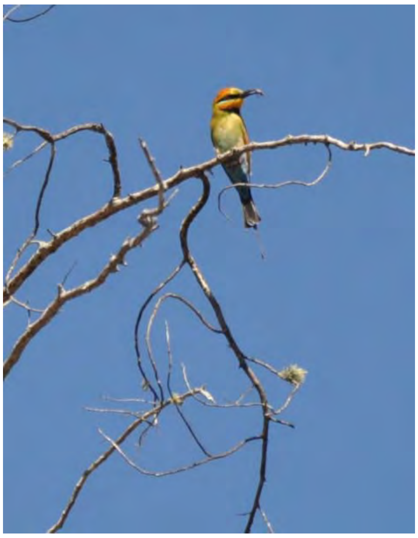


Plate 20: Riparian woodland; Rainbow Bee-eater foraging in riparian woodland

E8: Shrub grass woodland

There are approximately 28,225 ha of shrub grass woodland mapped in the study area. Shrub grass woodland is one of the most abundant habitat types in the study area (**Figure 19**). The majority of shrub grass woodland is located on the alluvial plains that run from the northeast to the south west of the study area. Other patches of shrub grass woodland are located on uplands in the south and northwest of the study area.

Shrub grass woodland has a canopy layer of mature eucalypts of approximately 5% - 35% projected foliage cover. The midstorey is often dominated by cypress, casuarinas and juvenile eucalypts and ranges from approximately two metres to 10m high. A second midstorey of lower shrubs, approximately one metre to two metres is often present. The groundcover is characterised by dense grasses, with leaf litter, logs and fallen bark and branches also present. The structure of this habitat type is variable with some areas comprising dense midstorey patches and other areas with a fairly sparse midstorey. The soil substrate is variable with areas of sandy loam, clay loam or sandy clay loam.

Fauna habitat features of shrub grass woodland include foraging resources (seeds, pollen and nectar), mosaics of groundcover density (provides tussocks and low shrubs to protect ground fauna from predators), canopy and midstorey structure suitable for perching and nesting, hollow-bearing trees, decorticating and fallen bark, logs and fallen branches (**Plate 21**).

A range of threatened birds, mammals and reptiles were observed in shrub grass woodland (**Appendix A5** and **Plate 21**). Nesting and breeding behaviours was observed in a range of threatened woodland birds in shrub grass woodland (**Plate 21**). Also, the dense cypress patches often occurring in shrub grass woodland are considered suitable daytime shelter trees for Koala (DSEWPaC, 2011b).


Plate 21: Shrub grass woodland; Grey-crowned Babblers building a nest in shrub grass woodland

E9: Shrubby woodland

There are approximately 10,003 ha of shrubby woodland mapped in the study area. Shrubby woodland is most commonly distributed on the uplands in the east of the study area. Smaller patches occur on the uplands in the south of the study area (**Figure 19**).

Shrubby woodland has a canopy layer of mature eucalypts of approximately 5% - 20% projected foliage cover. The midstorey is characterised by a dense shrubby layer of approximately one metre to six metres. The groundcover is often sparse, mainly comprising grasses, leaf litter with logs and fallen bark and branches also present. The soil substrate is loamy sand.

Fauna habitat features of shrubby woodland include foraging resources (seeds, pollen and nectar), a complex shrub layer, canopy and midstorey structure suitable for perching and nesting, hollow-bearing trees, decorticating and fallen bark, logs and fallen branches and areas of sandy soils suitable for burrowing (**Plate 22**).

A range of threatened birds and mammals were observed in shrub grass woodland (**Appendix A5** and **Plate 22**). Areas of deep sandy soils and high shrub density and diversity provide primary and secondary Pilliga Mouse habitat. The rough-barked eucalypts and decorticating bark provide roosting sites for microbats (**Plate 22**).

Plate 22: Shrubby woodland; microbat under decorticating bark

Appendix F: Technical reports

F1: Threatened ecological community assessment: comparison with legal descriptions

F2: Vegetation mapping report

F3: Vegetation impact modelling technical report

F4: Flora modelling technical report

F5: Pilliga Mouse habitat technical report

F6: Pilliga Mouse survey technical report

F7: Regional Koala assessment

F8: Ecological sensitivity analysis

F1: Threatened ecological community assessment: comparison with legal descriptions

1. Threatened Species Conservation Act 1995

This assessment addresses the NSW Scientific Committee Final Determination (NSW Scientific Committee 2002) for *White Box Yellow Box Blakely's Red Gum Woodland* under the TSC Act.

Scientific Committee determination	Assessment of field data
1. White Box Yellow Box Blakely's Red Gum Woodland is the name given to the ecological community characterised by the assemblage of species listed in paragraph 3. White Box Yellow Box Blakely's Red Gum Woodland is found on relatively fertile soils on the tablelands and western slopes of NSW and generally occurs between the 400 mm and 800 mm isohyets extending from the western slopes, at an altitude of c. 170 m 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.	'*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. Soil classification has shown that the topsoil present 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*'. The inherent soil fertility mapping undertaken by OEH (2013) supports this view with the subject plots surveyed occurring on areas of 'moderately low' fertility. **The soil fertility within the subject plots is not consistent the final determination.**
2. White Box Yellow Box Blakely's Red Gum Woodland includes those woodlands where the characteristic tree species include one or more of the following species in varying proportions and combinations - *Eucalyptus albens* (White Box), *Eucalyptus melliodora* (Yellow Box) or *Eucalyptus blakelyi* (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.	All subject plots analysed except one contained *Eucalyptus blakelyi* as a dominant or co-dominant species. *E. melliodora* and *E. albens* were not recorded in subject plots. The ground layer generally has a very low cover and is characterised by grasses and herbs. However, smaller shrubs are often present. At some sites, particular along the drainage line of Bohena Creek, the shrub layer is characterised by relatively thick clumps of the shrubs *Callistemon linearis* and *Leptospermum polygalifolium* subsp. *transmontanum*.
3. White Box Yellow Box Blakely's Red Gum Woodland is characterised by the following assemblage of species: 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	The number of native species within the subject plots ranged from 12 to 47. The total number of characteristic species within the subject plots ranged from four to 11. The percentage of the total number of characteristic species (95 in total) in the Final Determination that occurred within the subject plots ranged from 4% to 11%. The subject plots are dominated by species that are not characteristic, they contain a low percentage of characteristic species listed in the Final

Scientific Committee determination	Assessment of field data
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.	Determination, they contain a low frequency of characteristic species that are more common on higher fertility soils and the characteristic species that are present occur in low numbers and cover. **The subject plots are not consistent with this part of the final determination**.
4. Woodlands with *Eucalyptus albens* are most common on the undulating country of the slopes region while *Eucalyptus blakelyi* and *Eucalyptus melliodora* predominate in grassy woodlands on the tablelands. Drier woodland areas dominated by *Eucalyptus albens* often form mosaics with areas dominated by *Eucalyptus blakelyi* and *Eucalyptus melliodora* occurring in more moist situations, while areas subject to waterlogging may be treeless. *E microcarpa* is often found in association with *E. melliodora* and *E. albens* on the south western slopes. Woodlands including *Eucalyptus crebra*, *Eucalyptus dawsonii* and *Eucalyptus moluccana* (and intergrades with Eucalyptus albens), for example in the Merriwa plateau, Goulburn River National Park and western Wollemi National Park, are also included. Intergrades between *Eucalyptus blakelyi* and *Eucalyptus tereticornis* may also occur here.	The study area lies on the geographical boundary between the NSW western slopes and plains regions (Harden 1990). None of the subject plots contain *E. albens*. While most subject plots contain *E. blakelyi*, they are not located within the tablelands. Subject plots that contained *E. blakelyi* are located within and adjacent to ephemeral watercourses within the study area. However, they do not form a mosaic with drier woodland areas dominated by *E. albens*. The surrounding woodland areas are dry woodlands dominated mostly by *E. chloroclada*, *E. pilligaensis*, *E. crebra*, *E. fibrosa* and *Corymbia trachyphloia*. No subject plots contained *E. moluccana* (or intergrades with *E. albens*), *E. dawsonii* or *E. melliodora*. The study area is not located in or near the Merriwa plateau, Goulburn River National Park or western Wollemi National Park.
5. Latitudinal and climatic gradients in the patterns of species present are found across the range of the community (e.g. 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 (e.g. Prober 1996). Within White Box Yellow Box Blakely's Red Gum Woodland, species such as *Rostellularia adscendens*, *Chloris ventricosa*, *Rytidosperma racemosa*, *Brunoniella australis*, *Cymbopogon refractus*, *Swainsona galegifolia*, *Notelaea microcarpa*, *Stackhousia viminea*, *Olearia elliptica*, *Jasminum suavissimum*, *Plantago gaudichaudii*, *Dichanthium sericeum*, *Plantago debilis* and *Wahlenbergia communis* are generally more restricted to more northern areas (eg. Prober 1996). Some other species in White Box Yellow Box Blakely's Red Gum Woodland were generally restricted to southern areas. These include	Of the species listed as being restricted to more northern areas the following were recorded within subject plots: *Cymbopogon refractus*, *Swainsona galegifolia* and *Wahlenbergia communis*. Other northern species located within the woodland surrounding the subject plots but which were not recorded in the subject plots include *Chloris ventricosa*, *Rytidosperma racemosa*, *Dichanthium sericeum* and *Plantago debilis*. None of the species generally restricted to southern areas were recorded in the subject plots or within the study area. This simply reflects the location of the study area next to the North Western Slopes rather than the South Western Slopes.

Scientific Committee determination	Assessment of field data
Gonocarpus elatus, *Austrostipa blackii*, *Aristida behriana*, *Bracteantha viscosa*, *Rytidosperma auriculata* and *Austrostipa nodosa* (Prober 1996).	
6. White Box Yellow Box Blakely's Red Gum Woodland includes vegetation described as *Eucalyptus albens* alliance and *E. melliodora* / *E. blakelyi* alliance in Beadle (1981), the *Eucalyptus albens* 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).	Beadle (1981) states that the *E. melliodora* / *E. blakelyi* alliance is well defined (occurs between the 400 mm to 800 mm isohyets and at an altitude of approximately 170 m to 1200 m on the Northern Tablelands). The study area does not fall within this range. Moore (1953a,b) considers only the south-east Riverina area and does not describe vegetation within the Brigalow Belt South Bioregion. Prober and Thiele (1993) describe the distribution and ecology of *E. blakelyi* following Moore (1953a,b). 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, *E. melliodora* and *E. blakelyi* Maiden) can become locally dominant along non-permanent water courses or on deeper soils of valleys (Moore 1953a is cited). The references cited above concerning the Grassy White Box Woodlands describes *E. blakelyi* as an intergrade or as occurring in an association on valley flats or non-permanent watercourses within a mosaic of *E. albens*. The subject plots are not located within this position in the landscape and *E. blakelyi* is not associated with *E. albens* woodlands.
7. Related communities are the *Eucalyptus microcarpa*, *Eucalyptus pilligaensis* Grey Box/ *Eucalyptus populnea* Poplar Box communities of the western slopes and plains and the *Eucalyptus moluccana*, 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 *Eucalyptus pauciflora* grassy woodlands of the cooler parts of the southern tablelands are not covered by this Determination.	None of the vegetation communities sampled by the subject plots relate to the *Eucalyptus microcarpa*, *Eucalyptus pilligaensis* Grey Box / *Eucalyptus populnea* Poplar Box communities of the western slopes and plains. The study area is not in the Clarence, lower Hunter Valley, Western Sydney or the southern tablelands.
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.	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.

Scientific Committee determination	Assessment of field data
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 *Eucalyptus albens*, *E. melliodora* and *E. blakelyi* 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 of wholly removed by post European activities, and conversely, often remnants of these communities survive with these tree species largely intact but with 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).	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. 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.
9. 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).	It is likely that understorey of the vegetation sampled by subject plots has been modified in the past by limited grazing as well as altered fire regimes. However, the vegetation sampled by the subject plots consisted of intact woodland and was no longer used for grazing. The understorey was generally sparse with large areas of bare ground and dominant species frequently included *Aristida* sp., *Imperata cylindrica* and *Lomandra* spp. which are not typical of this ecological community. *Themeda australis* was not recorded in the subject plots, but has been observed as isolated individuals in the vicinity of the subject plots. *Poa* spp. and *Austrostipa aristiglumis* have not been recorded in the study area. The subject plots were also not dominated by *A. falcata*, *Rytidosperma* spp. or *Bothriochloa* spp. *A. ramosa* is a very widespread species and was recorded in a number of subject plots.

Scientific Committee determination	Assessment of field data
10. 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 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.	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.
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.	All of the vegetation within the subject plots in this analysis contained a ground, shrub and tree layer.
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.	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. Both of these National Parks include geological formations (including volcanics) from which relatively '*fertile soils'* are derived.
13. Fauna species of conservation significance found in some stands of White Box Yellow Box Blakely's Red Gum Woodland include, • *Aprasia parapulchella* - Pink-tailed Legless Lizard • *Burhinus grallarius* - Bush Stone-curlew • *Cacatua leadbeateri* - Major Mitchell's Cockatoo	Noted. Not related to the analysis.

Scientific Committee determination	Assessment of field data
• *Climacteris picumnus victoriae* - Brown Treecreeper • *Dasyurus maculatus* - Spotted-tailed Quoll • *Delma impar* - Striped Legless Lizard • *Grantiella picta* - Painted Honeyeater • *Hoplocephalus bitorquatus* - Pale-headed Snake • *Lathamus discolor* - Swift Parrot • *Lophoictinia isura* - Square-tailed Kite • *Melanodryas cucullata cucullata* - Hooded Robin • *Melithreptus gularis gularis* - Black-chinned Honeyeater • *Neophema pulchella* - Turquoise Parrot • *Ninox connivens* - Barking Owl • *Petaurus norfolcensis* - Squirrel Glider • *Phascolarctos cinereus* - Koala • *Polytelis swainsonii* - Superb Parrot • *Pomatostomus temporalis temporalis* - Grey-crowned Babbler • *Pyrrholaemus sagittata* - Speckled Warbler • *Saccolaimus flaviventris* - Yellow-bellied Sheathtail-bat • *Stagonopleura guttata* - Diamond Firetail • *Synemon plana* - Golden Sun Moth • *Tyto novaehollandiae* - Masked Owl • *Varanus rosenbergi* - Rosenberg's Goanna • *Xanthomyza phrygia* - Regent Honeyeater A number of plant species of conservation significance are likely to occur in White Box Yellow Box Blakely's Red Gum Woodland • *Ammobium craspedioides* • *Bothriochloa biloba* • *Dichanthium setosum* • *Discaria pubescens* • *Diuris* spp. • *Prasophyllum petilum* • *Pterostylis* spp. • *Rutidosis leptorrhynchoides* • *Swainsona* spp.	

Scientific Committee determination	Assessment of field data
A number of key threatening processes also occur in White Box Yellow Box Blakely's Red Gum Woodland. These include: Clearing of native vegetation, Predation by the European Red Fox *Vulpes vulpes*, Predation by the Feral Cat, *Felis catus*.	
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.	Noted. Not related to the analysis.
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 endangered ecological community White Box Yellow Box Blakely's Red Gum Woodland.

2. Environment Protection and Biodiversity Conservation Act 1999

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 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.

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.

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

General Description paragraph	Assessment
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 (*Eucalyptus microcarpa* or *E. moluccana*) may also be dominant or co-dominant. The tree-cover is generally discontinuous	The understory within the subject plots is not considered to be species-rich nor is it characterised by native tussock grasses. All subject plots except for one contained *Eucalyptus blakelyi* as a dominant or co-dominant species.

General Description paragraph	Assessment
and consists of widely-spaced trees of medium height in which the canopies are clearly separated (Yates & Hobbs 1997).	Tree-cover in the subject plots ranged from discontinuous along larger creeks like Bohena Creek and continuous on smaller tributaries.
In its pre-1750 state, this ecological community was characterised by: • 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.	The subject plots are not characterised by tussock grasses. Many of the subject plots are dominated by the graminoid *Lomandra longifolia* and the rhizomatous (underground stems) perennial grass *Imperata cylindrica*. The overstorey of most subject plots is dominated by *E. blakelyi*, although some subject plots are dominated by *Angophora floribunda* or *E. chloroclada*. Most subject plots have a sparse shrub layer, although some subject plots have dense patches of shrubs of *L. polygalifolium* subsp. *transmontanum* or *Callistemon linearis*. **The subject plots are not consistent with this part of the listing advice.**
Associated, and occasionally co-dominant, trees include, but are not restricted to: Grey Box (*Eucalyptus microcarpa*), Fuzzy Box (*E. conica*), Apple Box (*E. bridgesiana*), Red Box (*E. polyanthemos*), Red Stringybark (*E. macrorhyncha*), White Cypress Pine (*Callitris glaucophylla*), Black Cypress Pine (*C. endlicheri*), Long-leaved Box (*E. goniocalyx*), New England Stringybark (*E. caliginosa*), Brittle Gum (*E. mannifera*), Candlebark (*E. rubida*), Argyle Apple (*E. cinerea*), Kurrajong (*Brachychiton populneus*) and Drooping She-oak (*Allocasuarina verticillata*) (Austin et al. 2000; Beadle 1981; Fischer et al. 2004; NSW National Parks & Wildlife Service 2002; Prober & Thiele 2004).	Other trees in subject plots included *E. conica* (Fuzzy Box), *C. endlicher*i (Black Cypress Pine), *Brachychiton populneus* (*Kurrajong*). These species are not restricted to *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* but also occur in other habitats and vegetation communities on the western slopes and plains.
This ecological community occurs in areas where rainfall is between 400 mm and 1200 mm `per annum, on moderate to highly fertile soils at altitudes of 170 m to 1200 m (NSW Scientific Committee 2002).	The subject plots occur in an area that receives between 400 mm and 1200 mm of rainfall. However, the subject 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. The subject plots are above 170 m and below 1200 m altitude. **The subject plots are not consistent with this part of the listing advice.**
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	The location of the study area is outside of and north of the mapping in Prober and Thiele (2004). In addition it

General Description paragraph	Assessment
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 2004). 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 2004).	is outside and west of the area mapped in Prober (1996). The subject plots are not located in either the tablelands or eastern slopes, and the vegetation dominated by *E. blakelyi* along creeks which were sampled by the subject plots does not form mosaics with *E. albens*.
The Box – Gum Grassy Woodland and Derived Grassland ecological community intergrades with Western Grey Box (*Eucalyptus microcarpa*) woodlands in the west (Prober and Thiele 2004). Sites dominated by Western Grey Box (*E. microcarpa*) or Coastal Grey Box (*E. moluccana*) 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.	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 *E. microcarpa* woodlands.
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 2004). In 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 (*Xanthomyza phrygia*), Squirrel Gliders (*Petaurus norfolcensis*) and Superb Parrots (*Polytelis swainsonii*) (NSW Scientific Committee 2002).	Thiele and Prober (2000) note that much of the original extent of *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* has been cleared for agriculture. The vegetation in and surrounding the subject plots has not been cleared for agriculture. 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 limited grazing in the past, however, this has ceased and there is regeneration of the overstorey species.
Kangaroo Grass (*Themeda triandra*, also known as *Themeda australis*) and Snow Grass (*Poa sieberiana*) 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.	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 *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* it would be

General Description paragraph	Assessment
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 (*Microseris lanceolata*)), lilies (e.g. Milkmaids (*Burchardia umbellata*)), pea plants (e.g. Australian Trefoil (*Lotus australis*)) and orchids (e.g. Purple Diuris (*Diuris punctata*)). 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).	expected that the dominant ground layer species would be *Themeda australis* (Kangaroo Grass) and *Poa sieberiana* (Snow Grass). However, neither of these species was recorded within the subject plots. In addition, none of the cited tall perennial herbs were recorded. **The subject plots are not consistent with this part of the listing advice.**
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 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 2004).	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 diversity is relatively low, despite the relatively lower levels of intensity of disturbance.
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,	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 *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*.

General Description paragraph	Assessment
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).	**The subject plots are not consistent with this part of the listing advice.**
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 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.	Prober and Thiele (1993) note that 'on more marginal sites, usually with shallow or sandy soils, shrubs become more abundant in the understorey'. 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 *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* occurs. In the subject plots the shrub cover is generally low (less than 5%) although can be up to 20%.
Conclusion	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: 1. The subject plots are located on low to moderately low fertility soil 2. The ground layer remains largely intact and is not dominated by tussock grasses. 3. 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

General Description paragraph	Assessment
	effects (soil compaction, weed invasion) have also not been significant. 4. 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.

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F2: Vegetation mapping report

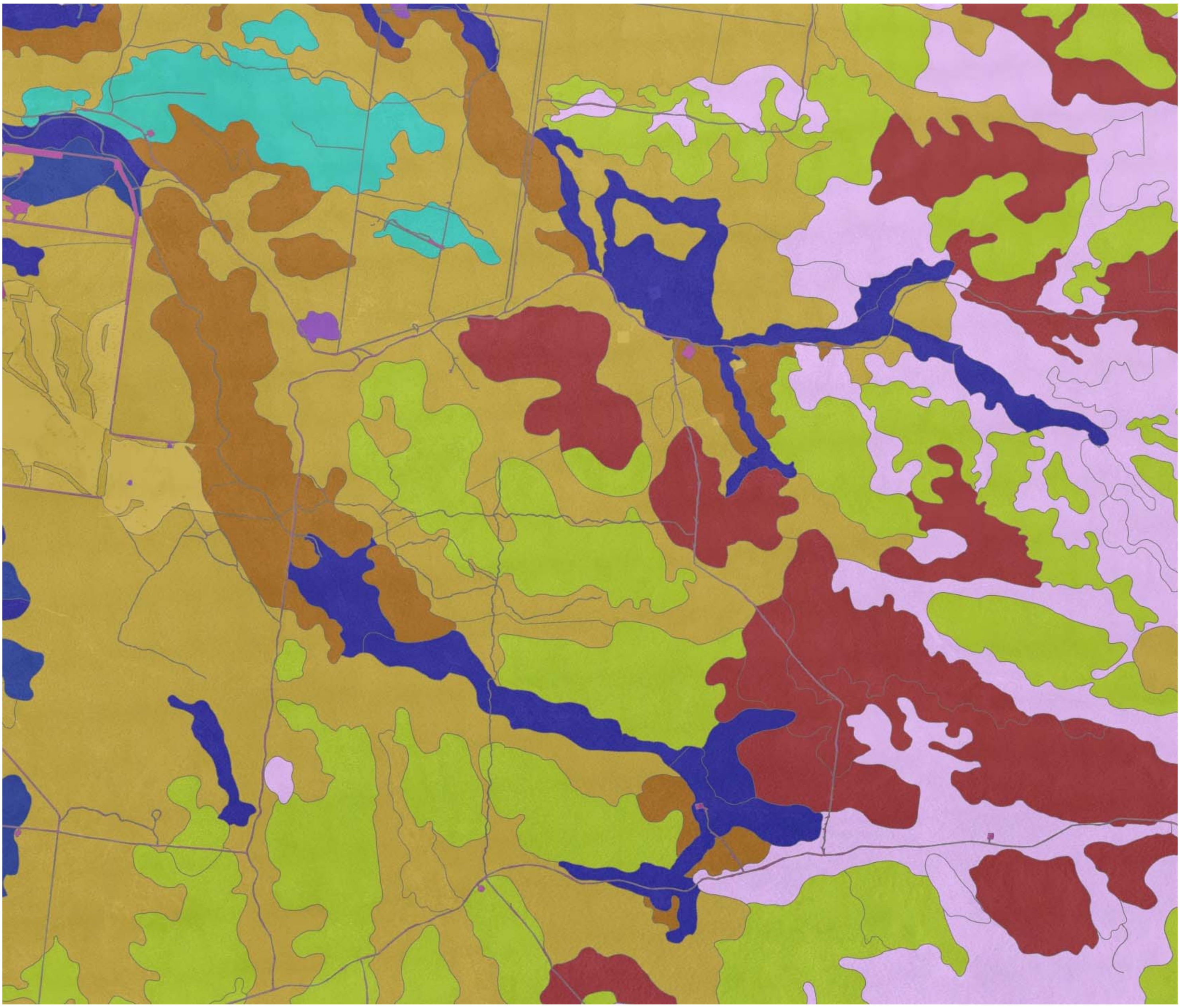
ecological AUSTRALIA

Narrabri Gas Project

Vegetation Mapping

Prepared for
Santos NSW (Eastern) Pty Ltd

October 2015



This report should be cited as 'Eco Logical Australia 2015. *Narrabri Gas Project - Vegetation Mapping*. Prepared for Santos NSW (Eastern) Pty Ltd.'

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Abbreviations

Abbreviation	Description
BVT	Biometric Vegetation Types
DNG	Derived Native Grassland
DoE	Australian Government Department of the Environment
ELA	Eco Logical Australia Pty Ltd
EPBC Act	Commonwealth *Environment Protection and Biodiversity and Conservation Act 1999*
GIS	Geographic Information System
OEH	NSW Office of Environment and Heritage
RVC	Regional Vegetation Community
TSC Act	NSW *Threatened Species Conservation Act 1995*
VCA	Vegetation Classification and Assessment

Executive summary

Eco Logical Australia (ELA) was engaged by the Proponent to prepare a detailed vegetation map for the Narrabri Gas Project which covers approximately 95,077 hectares in the north-east Pilliga Forest (the study area). The vegetation map and associated products will form the base layer to be assessed as part of the ecological assessment for the Environmental Impact Statement for the Narrabri Gas Project.

A total of 327 full floristic BioMetric vegetation plots and over 1,000 rapid vegetation validation plots have been surveyed in the study area which form the basis for vegetation community classification. Vegetation mapping was undertaken using a 'heads-up' on screen digitising approach (utilising high quality aerial photography, Light Detection and Ranging datasets including a Canopy Height Model, contours and drainage) using a Geographic Information System (GIS) running ArcGIS 10.2.

Vegetation communities were attributed in accordance with the Plant Community Types of the NSW Vegetation Classification Assessment (NSWVCA) (Allen et al. 2010) at a scale of 1:10,000 to help inform planning/design decisions for the Narrabri Gas Project. Vegetation mapping also included Endangered Ecological Communities, land use classification and attribution of each Plant Community Types to a Biometric Vegetation Type (BVT) for use in the assessment and quantifications of suitable offsets for the Narrabri Gas Project.

A total of 22 Plant Community Types were identified in the study area, four of which are listed as Endangered Ecological Communities under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and two under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Derived Native Grassland (DNG), cropped and pasture improved land, as well as clearings, roads and trails, and dams were also delineated in the mapping process to help inform infrastructure locations to minimise impacts on biodiversity values.

The vegetation map was determined to have an accuracy of 89% for areas within the main body of the Pilliga Forest. The mapping products which accompany this technical report can be reliably used to determine the Plant Community Type, Endangered Ecological Community, Biometric Vegetation Type or land use at a given point in the study area.

This vegetation mapping will be used to develop additional Geographic Information System products such as constraints mapping, development of clearing limits, Ecological Sensitivity Analysis, fauna habitat mapping and quantification of suitable offsets for the Narrabri Gas Project.

1 Introduction

Eco Logical Australia was engaged by the Proponent to prepare a detailed vegetation map for the Narrabri Gas Project which covers approximately 95,077 hectares in the north-east Pilliga Forest (the study area, **Figure 1**). The vegetation map and associated products will form the base layer to be assessed as part of the ecological assessment for the Environmental Impact Statement for the Narrabri Gas Project.

Whilst Forest Types Mapping (Lindsay 1967) is available for areas of State Forest within the study area and Regional Vegetation Class mapping is available for the entire Namoi Catchment Management Area, they are only considered to be reliable at a regional scale (e.g. 1:50,000) and therefore not suitable for site-scale assessment.

This project mapped all vegetation within the study area at a 1:10,000 scale. The scale and accuracy of the resultant mapping product will improve the Proponents' ability to avoid and minimise impacts on significant ecological values throughout the planning process.

1.1 Aims and objectives

The primary aim of this project was to map the vegetation communities occurring within the study area in accordance with the Plant Community Types of the NSW Vegetation Classification Assessment at a scale of 1:10,000 to help inform planning/design decisions for the Narrabri Gas Project.

This project also aimed to identify and map Endangered Ecological Communities, classify land use and attribute each Plant Community Type to a Biometric Vegetation Type for use in the assessment and quantifications of suitable offsets for the Narrabri Gas Project.

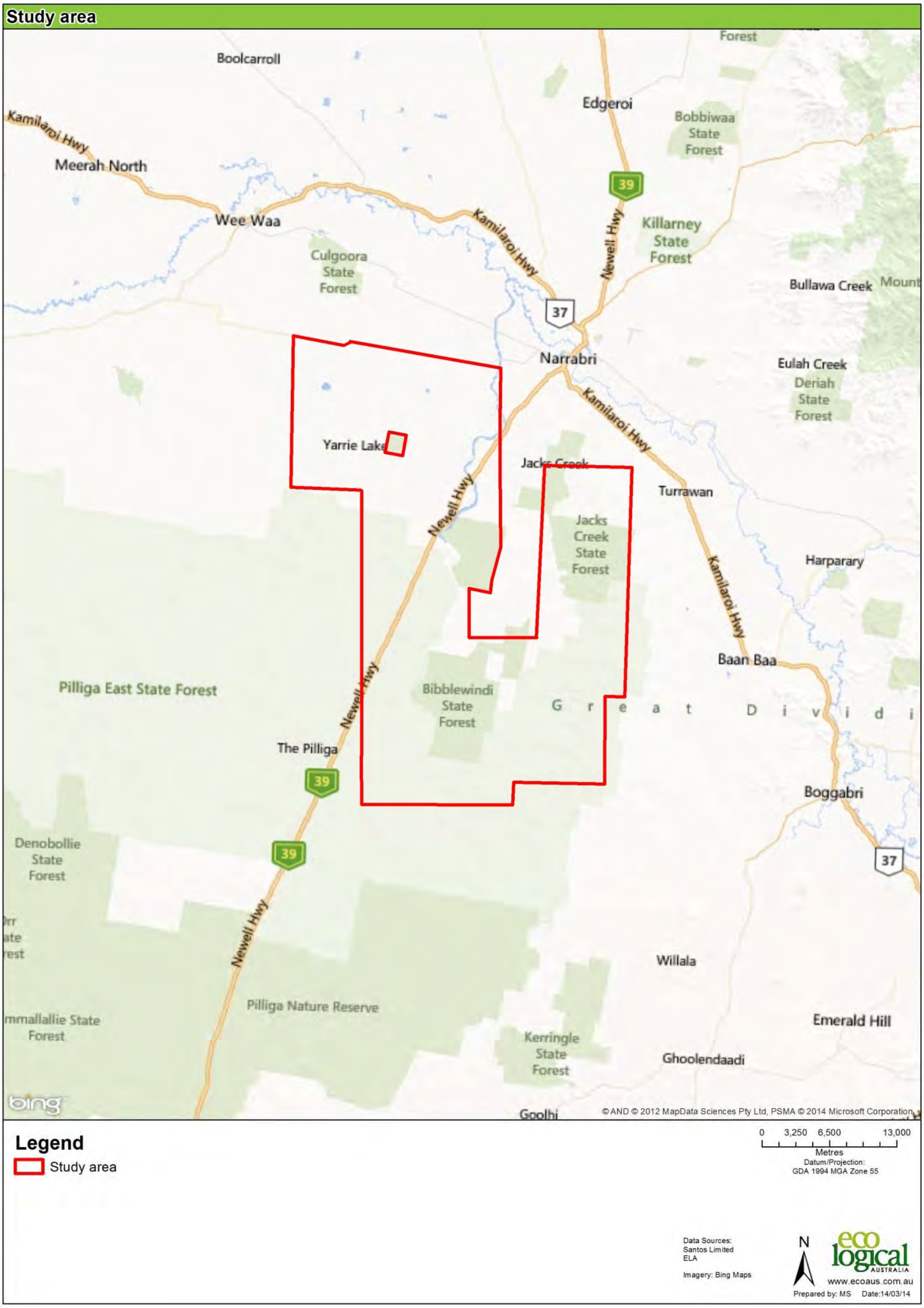

Figure 1: Study area

2 Methodology

Vegetation mapping was undertaken using a 'heads-up' on screen digitising approach (utilising high quality aerial photography, Light Detection and Ranging datasets including a Canopy Height Model (contours and drainage) using a Geographic Information System running ArcGIS 10.2.

Vegetation communities were attributed in accordance with the Plant Community Types of the NSW Vegetation Classification Assessment (Allen et al. 2010) as they provide the best representation of the vegetation in the study area and are useful for delineating fauna habitat. Biometric Vegetation Types have been attributed for use in the assessment and in the determination of suitable offsets for the Narrabri Gas Project.

2.1 Data sets

A range of datasets were used, including high quality aerial imagery, previous vegetation mapping (Lindsay 1967, ELA 2009), the Canopy Height Model, vegetation survey plot data and rapid vegetation validation undertaken by Eco Logical Australia since 2010, as well as contour and drainage layers which were derived from Light Detection and Ranging (**Table 1**). A more detailed description of the data utilised, including limitations is provided in **Appendix A**.

Table 1: Data utilised

Data	Purpose
High resolution aerial imagery (Schlencker Mapping 2010; RPS Group 2013)	Using Aerial Photograph Interpretation, distinct patterns in the imagery representing potential vegetation community boundaries were identified and mapped.
Canopy Height Model (Schlencker Mapping 2010; RPS Group 2013)	Vegetation structure and cover was used in combination with Aerial Photograph Interpretation to delineate vegetation community boundaries.
Vegetation mapping products including: • Forest Types Mapping (Lindsay 1967) • Namoi Catchment Management Authority Regional Vegetation Class Mapping (ELA 2009)	Existing vegetation mapping was used as a guide to the occurrence, boundaries and extent of vegetation communities, as well as the assignment of Plant Community Types.
Vegetation survey data including: • Eco Logical Australia vegetation survey plots (2010-2014) including soil classification • Eco Logical Australia rapid vegetation validation (2010-2014) including soil classification • Eco Logical Australia Pilliga Mouse rapid habitat assessments (2013)	Field survey data was used to identify boundaries between vegetation communities, classify soils and assign Plant Community Types.

Data	Purpose
Other Light Detection and Ranging derived data including: • Contour layer (Schlencker Mapping 2010; RPS Group 2013) • Drainage layer (ELA 2013; ELA 2014)	Topography, drainage and landscape position
Tracks and trails (Eastern Star Gas 2009)	Identify accessible areas for vegetation and soil assessments
NSW Office of Environment and Heritage land use data (OEH 2009)	Identify areas of cropping and improved pasture.

2.2 Field survey

Field surveys including 327 full floristic BioMetric vegetation plots and over 1,000 rapid vegetation validation plots have been undertaken by Eco Logical Australia in the study area since 2010 (**Figure 2**).

A total of 327 full floristic BioMetric vegetation plots have been surveyed across the study area. Data recorded at these sites generally included all vascular plant species present, cover abundance of each species in accordance with a modified six-point Braun-Blanquet scale, cover abundance of each structural layer (canopy, midstorey, groundcover), weed abundance, hollow presence and size classification length of fallen logs and a soil classification (colour and texture).

Rapid vegetation validation was undertaken using ruggedized Personal Digital Assistants loaded with ArcPad 10.0 software and relevant Geographic Information System datasets (aerial photography, vegetation mapping, roads etc.). This process involved driving on established forestry roads and trails within the study area and surveying a rapid vegetation validation plot at each vegetation community boundary. The area between two successive points is then assigned the vegetation community allocated at the first point.

Plant Community Types, dominant canopy midstorey and groundcover species, low shrub cover, soil type, fire history, and additional comments (e.g. midstorey density due to regrowth) were recorded at each rapid vegetation validation plot. A track log was also recorded to identify the area traversed during the surveys. Rapid vegetation validation plots are less comprehensive than full floristic BioMetric vegetation plots, however they allow for rapid identification of Plant Community Types and identify boundaries between vegetation communities within the landscape.

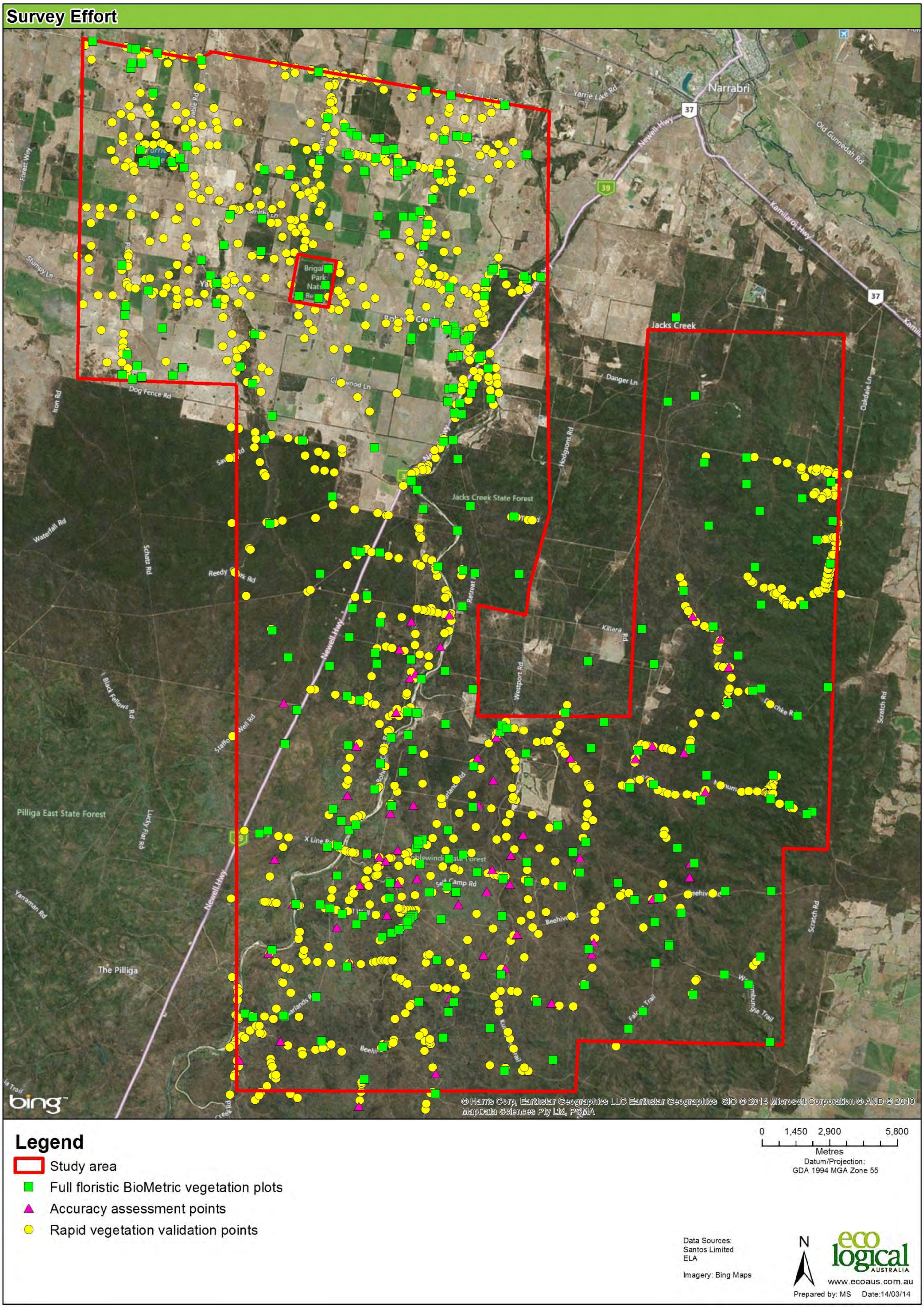

Figure 2: Survey effort

2.3 Vegetation and land use mapping

Vegetation mapping was undertaken using a 'heads-up' on screen digitising approach in ArcGIS10.2. Data was loaded into the Geographic Information System and rapid vegetation validation plots were combined with full floristic BioMetric vegetation plots to form a combined dataset which was overlain on the high quality aerial imagery.

The rapid vegetation validation points were used as an initial guide to identifying vegetation community boundaries. Aerial Photograph Interpretation was then used in combination with the Canopy Height Model to identify distinct patterns in the imagery representing potential vegetation community boundaries. The Canopy Height Model was particularly useful in areas with visually homogenous vegetation as it allows the classification and measurement of vegetation structure (i.e. canopy, midstorey and groundcover heights and cover).

Vegetation community boundaries (polygons) were then digitised at a 1:10,000 scale. Supplementary datasets such as contours, drainage layers and soil classification were used to help inform the Aerial Photograph Interpretation to delineate boundaries between vegetation communities. Forest Types Mapping (Lindsay 1967) and the Namoi Catchment Management Authority Regional Vegetation Class Mapping (ELA 2009) were used to guide and/or validate the allocation and extent of each Plant Community Type mapped. NSW Office of Environment and Heritage land use mapping (OEH 2009) was used to delineate areas of cropping and improved pasture with Aerial Photograph Interpretation undertaken to identify additional areas not mapped by the NSW Office of Environment and Heritage.

Each polygon was assigned a Plant Community Type based on expert opinion on floristic composition, vegetation structure, landscape position and soil type. Individual polygons were assigned the following attributes:

- Plant Community Type. Derived Native Grassland was also assigned a Plant Community Type based on the most likely vegetation community from which it was likely to have been derived.
- Endangered Ecological Community status under the EPBC Act and TSC Act
- Land use:
    1. Native vegetation
    2. Derived Native Grassland
    3. Dam
    4. Creek bed
    5. Other – Cropping
    6. Other – Improved pasture
    7. Other – Previous evidence of pasture improvement.
- Condition class:
    1. Good (remnant vegetation)
    2. Moderate (thinned vegetation and/or moderate weed cover)
    3. Low (sparse or mostly cleared)
    4. Pasture improved.
- Accuracy score (1 to 5):
    1. Accessed (validated – Category 1)
    2. Not accessed but observed from adjoining property, or adequately known from existing data (validated - Category 2)
    3. Not accessed but reasonable confidence based on Aerial Photograph Interpretation review (not validated – Category 3)
    4. Not accessed and low to moderate confidence (not validated – Category 4)

5. Not accessed and no confidence (not validated – Category 5)

- Attribution of Regional Vegetation Classes and Biometric Vegetation Types.

Vegetation mapping was generally undertaken at a 1:10,000 scale, however areas that were not accessed during vegetation surveys were often inspected carefully at a finer scale. Roads, trails, dams, existing infrastructure and other clearings were separated from the vegetation mapping.

Vegetation mapping validation occurred continuously throughout the life of the project with polygon boundaries and Plant Community Types updated where necessary.

2.4 Accuracy assessment

Approximately 20% of the combined vegetation survey points were randomly selected and withheld as 'accuracy assessment points' in order to conduct a desktop accuracy assessment of the final vegetation map (**Figure 2**). The accuracy assessment points were withheld for areas within the main body of the Pilliga Forest only; hence the accuracy assessment does not apply to the entire vegetation map.

The sparser vegetation north of the Pilliga Forest (within the study area) facilitated a higher level of survey and assessment than what was possible within the Pilliga Forest. This has resulted in mapping in these areas which is inherently more accurate.

For the areas within the Pilliga Forest, the accuracy assessment followed this procedure:

- If the Plant Community Type assigned to a polygon corresponded with the Plant Community Type recorded at the vegetation survey point, it received an accuracy score of '1'.
- If the Plant Community Type assigned to a polygon did not correspond with the Plant Community Type recorded at the vegetation survey point but was within 50 m to the boundary of a polygon with the corresponding Plant Community Type (approximately 50 m) it was assigned an accuracy score of '0.5'.
- If the Plant Community Type assigned to the polygon did not correspond to the Plant Community Type recorded at the vegetation survey point it was assigned an accuracy score of '0'.
- The sum of all accuracy scores was divided by the total number of accuracy assessment points and multiplied by 100 to develop an accuracy score.

Following completion of the accuracy assessment, all accuracy assessment points which received a '0.5' or '0' score were amended to the correct Plant Community Type based on field survey data.

3 Results

3.1 Plant Community Types

A total of 22 Plant Community Types (totalling 80,398 ha of native vegetation) including one previously undescribed vegetation community were mapped in the study area (**Table 2** and **Figure 3**). One vegetation community (ID40X) does not correspond with the Plant Community Types of the NSW Vegetation Classification Assessment. Under a formal assessment utilising Plant Community Types, this community would be best allocated to Plant Community Type 405. A supplementary description of this community has been developed based on the cover-abundance of species recorded within full floristic BioMetric vegetation plots (**Appendix C**).

A more detailed analysis of Plant Community Types by land use and condition is provided in **Table 6** of **Appendix E**. A detailed description of Plant Community Types according to Allen et al. (2010) can be found in **Appendix C**.

Table 2: Summary of Plant Community Types identified in the study area

Plant Comm. ID	Common name	Total area mapped (ha)
27	*Acacia pendula* (Weeping Myall) open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	209.26
35	*Acacia harpophylla* (Brigalow) – *Casuarina cristata* (Belah) open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	6,695.19
55	*Casuarina cristata* (Belah) woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	678.94
78	*Eucalyptus camaldulensis* (River Red Gum) riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	10.49
88	*Eucalyptus pilligaensis* (Pilliga Box) - *Callitris glaucophylla* (White Cypress Pine) - *Allocasuarina luehmannii* (Buloke) shrubby woodland in the Brigalow Belt South Bioregion	5,946.61
141	*Melaleuca uncinata* (Broombush) - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	1,034.76
202	*Eucalyptus conica* (Fuzzy Box) woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions	589.82
256	*Eucalyptus viridis* (Green Mallee) tall mallee woodland on rises in the Pilliga - Goonoo regions, southern BBS Bioeregion	20.33
379	*Eucalyptus rossii* (Inland Scribbly Gum) - *Corymbia trachyphloia* (White Bloodwood) – *Eucalyptus macrorhyncha* (Red Stringybark) – *Eucalyptus endlicheri* (Black Cypress Pine) shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion	103.56

Plant Comm. ID	Common name	Total area mapped (ha)
397	*Eucalyptus populnea* subsp. *bimbil* (Poplar Box) – *Callitris glaucophylla* (White Cypress Pine) shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	762.80
398	*Eucalyptus crebra* (Narrow-leaved Ironbark) – *Callitris glaucophylla* (White Cypress Pine) - *Allocasuarina luehmannii* (Buloke tall) open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north BBS Bioregion	23,975.35
399	*Eucalyptus blakelyi*) (red gum) - *Angophora floribunda* (Rough-barked Apple) +/- *Leptospermum polygalifolium* (tea tree) sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	1,093.46
401	*Angophora floribunda* (Rough-barked Apple) - *Eucalyptus blakelyi* and *Eucalyptus chloroclada* (red gum) - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	7,580.41
402	*Eucalyptus sideroxylon* (Mugga Ironbark) - *Callitris glaucophylla* (White Cypress Pine) - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	358.20
404	*Eucalyptus fibrosa* (Red Ironbark) - *Corymbia trachyphloia* (White Bloodwood) -/+ *Acacia burrowii* (Burrows Wattle) heathy woodland on sandy soil in the Pilliga forests	9,982.488
405	*Corymbia trachyphloia* (White Bloodwood) - *Eucalyptus fibrosa* (Red Ironbark) - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	6,650.54
406	*Corymbia trachyphloia* (White Bloodwood) – *Acacia cheelii* (Motherumbah) - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	3,232.39
408	*Eucalyptus chloroclada* (Dirty Gum (Baradine Gum)) – *Callitris endlicheri* (Black Cypress Pine) - *Corymbia trachyphloia* (White Bloodwood) shrubby woodland on of the Pilliga forests and surrounding region	3,188.25
418	*Callitris glaucophylla* (White Cypress Pine) - *Eucalyptus melanophloia* (Silver-leaved Ironbark) - *Geijera parviflora* (Wilga shrub) grass woodland of the Narrabri-Yetman region, BBS Bioregion	131.59
425	*Acacia triptera* (Spur-wing Wattle) heath on sandstone substrates in the Goonoo – Pilliga forests Brigalow Belt South Bioregion	366.69
428	*Corymbia tessellaris* (Carbeen) - *Callitris glaucophylla* (White Cypress Pine) - *Acacia leiocalyx subsp. leiocalyx* (Curracabah) - *Eucalyptus albens* (White Box) tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	15.03
40X	White Bloodwood – *Eucalyptus chloroclada* (Dirty Gum (Baradine Gum)) – *Angohpora floribunda* (Rough Barked Apple) – *Callitris endlicheri* (Black Cypress Pine) heathy open woodland on deep sand in the Pilliga forests	7,772.162
Other	Includes cleared, creek bed, dams and improved pasture	14,678.37
Total		**95,076.68**

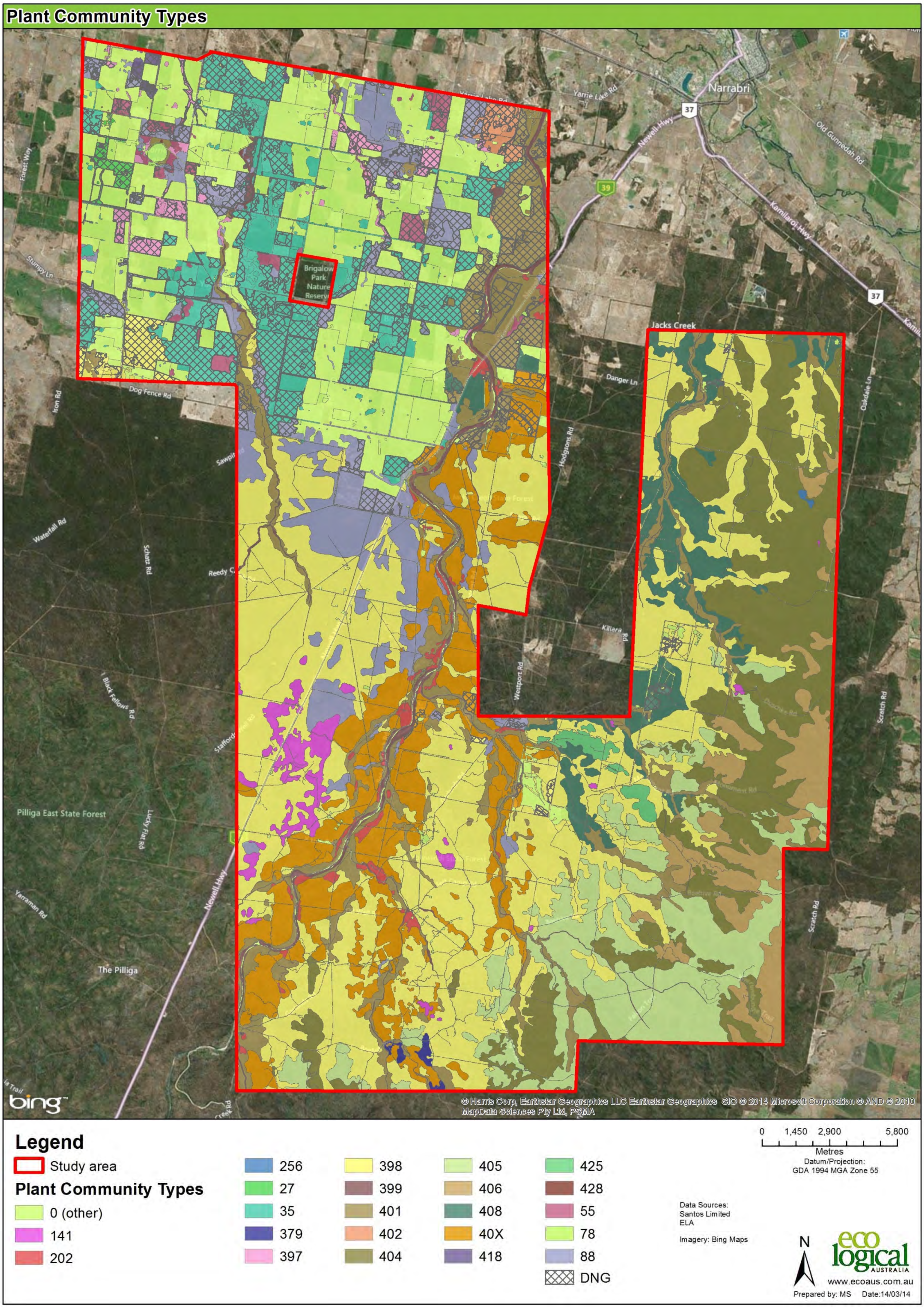

Figure 3: Plant Community Types

3.2 Biometric Vegetation Types

Biometric Vegetation Types are a higher order vegetation class than Plant Community Types and are used in regional biodiversity planning (e.g. Property Vegetation Plans and Biobanking). The 22 Plant Community Types mapped in the study area convert to 13 Biometric Vegetation Types (**Table 3** and **Figure 4**).

The Biometric Vegetation Types which constitute the greatest proportion of the study area include *Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion* (32%), *White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion* (25%) and *Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion* (9%).

Table 3: Biometric Vegetation Types in the study area

BVT ID	Biometric Vegetation Type	Total area mapped (ha)
NA102	Belah woodland on alluvial plains in central-north NSW (Benson 55)	678.94
NA117	Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion (Benson 35)	6,695.19
NA121	Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (Benson 141)	1,401.45
NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion	30,929.38
NA126	Carbeen woodland on alluvial soils (Benson 71)	15.03
NA141	Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (Benson 202)	589.82
NA143	Green Mallee scrub on sandstone rises in the Brigalow Belt South Bioregion (Benson 179)	20.33
NA160	Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland on Jurassic Sandstone of outwash plains (Benson 255)	358.20
NA179	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)	6,841.00
NA193	River Red Gum riverine woodlands and forests in the Nandewar and Brigalow Belt South Bioregions (Benson 78)	10.49
NA197	Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion	8,673.81
NA219	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions (Benson 27)	209.26
NA227	White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion	23,975.35
Other	Includes cleared, creek bed, dams and improved pasture	14,678.37
Total		**95,076.68**

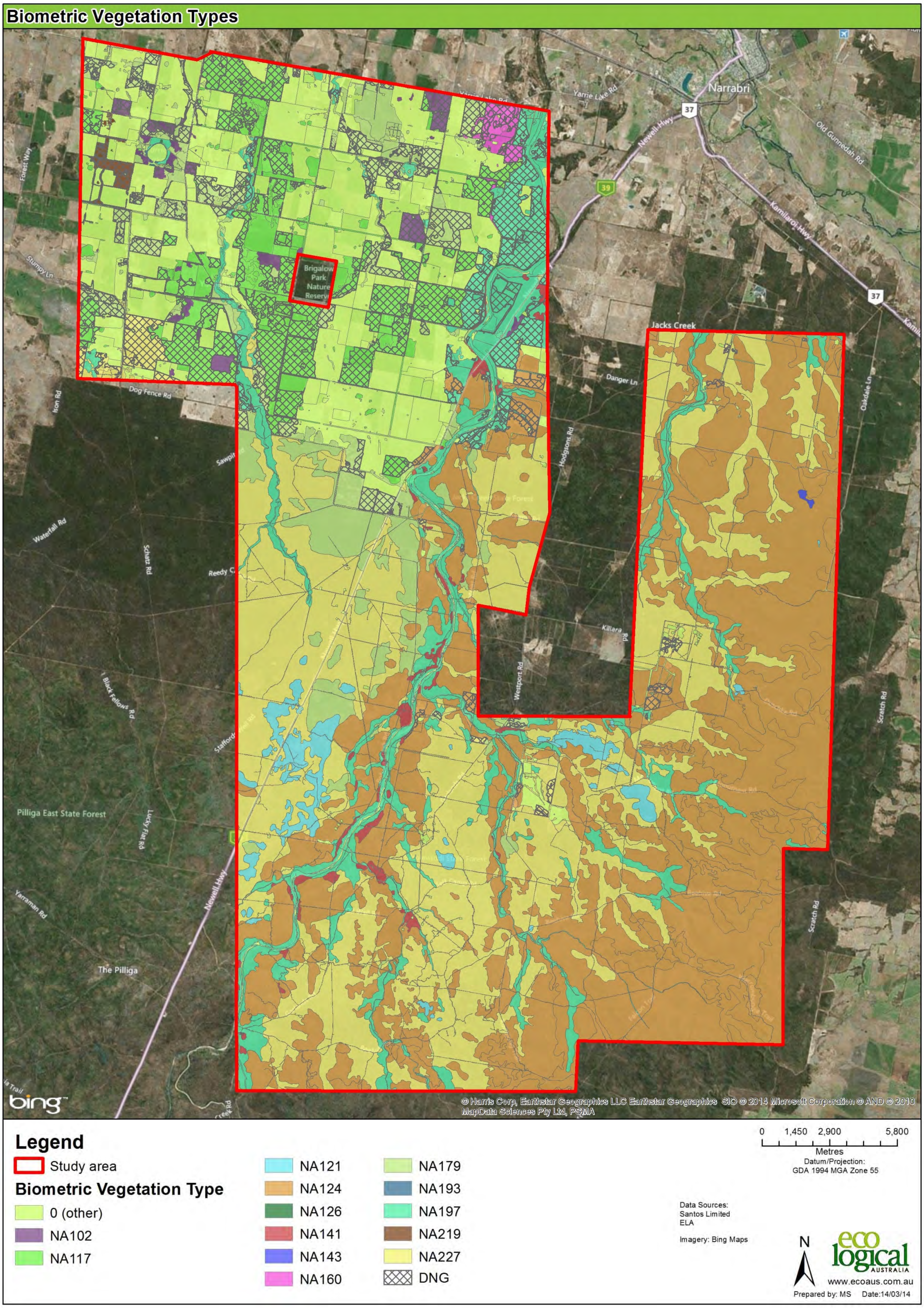

Figure 4: Biometric Vegetation Types

3.3 Endangered Ecological Communities

Four of the mapped Plant Community Types qualify as Endangered Ecological Communities (with two of these Endangered Ecological Communities being further divided by status under the EPBC Act and TSC Act due to condition). **Table 4** provides a summary of the area of each Endangered Ecological Community in the study area and **Figure 5** shows Endangered Ecological Communities in relation to the study area.

- ID27 Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions. Remnant patches that are > 5 ha in size and have > 5% canopy cover qualify as '*Weeping Myall Woodlands*' under the EPBC Act and '*Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions*' under the TSC Act (DoE 2014; OEH 2014). Areas of ID27 with scattered trees also qualify as the TSC Act listed community. Areas of Derived Native Grassland attributed with ID27 do not qualify as an Endangered Ecological Community.
- ID35 Brigalow – Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion. Remnant patches of ID35 that have not been cleared for over 15 years qualify as *'Brigalow (<u>Acacia harpophylla</u> dominant and co-dominant)'* under EPBC Act and as '*Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions*' under the TSC Act. Areas of ID35 that do not meet this requirement may still be considered the TSC Act listed community provided there is regenerating Brigalow present. Areas of Derived Native Grassland attributed with ID35 do not generally qualify as an Endangered Ecological Community.
- ID 202 Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions is listed as '*Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions*' under TSC Act (OEH 2014).
- ID428 Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion is listed as '*Carbeen Open Forest community in the Darling Riverine Plains and Brigalow Belt South Bioregions*' under the TSC Act (OEH 2014).

Table 4: Endangered Ecological Communities

Plant Comm. ID	Endangered Ecological Community	TSC Act area (ha)#	EPBC Act area (ha)
27	Weeping Myall Woodlands (EPBC Act) Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions (TSC Act)	36.00	32.52
35	Brigalow (Acacia harpophylla dominant and co-dominant) (EPBC Act) Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions (TSC Act)	2,467.97	2,447.35
202	Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions (TSC Act)	588.40	N/A
428	Carbeen Open Forest community in the Darling Riverine Plains and Brigalow Belt South Bioregions (TSC Act)	15.03	N/A
Total		3,107.40	2,479.87

TSC Act area includes the EPBC Act area

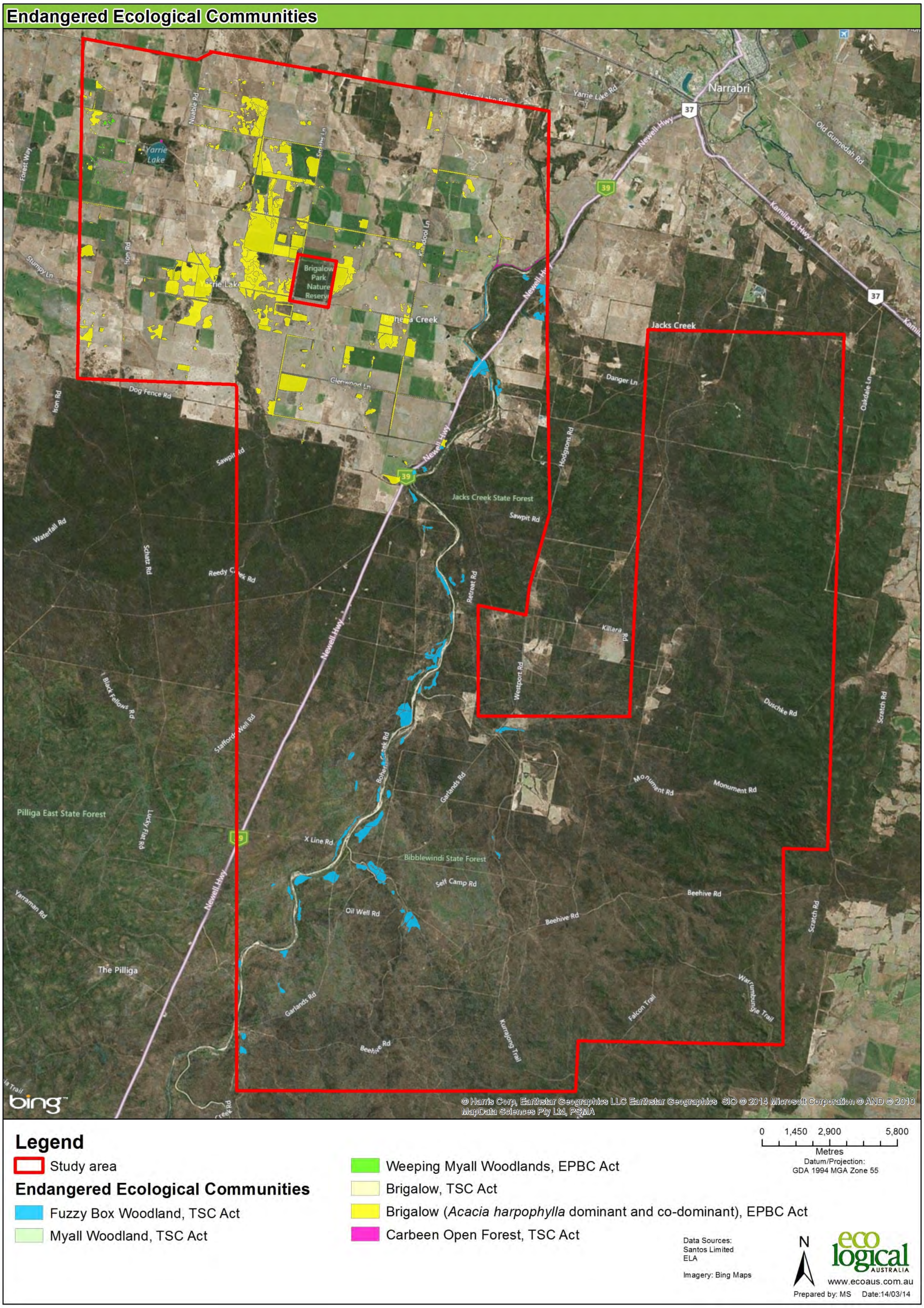

Figure 5: Endangered Ecological Communities

3.4 Land use

Eight land use classes were mapped within the study area (**Table 5** and **Figure 6**). The predominant land use is native vegetation totalling over 71,000 ha, which constitutes 75% of the total footprint of the study area. State Forest tenure accounts for 75% (or 53,000 ha) of this land use which is approximately 55% of the entire study area. The second most dominant land use is 'grazing' with a combined 24% of the study area. Notably of this 24%, Derived Native Grassland constitutes 10% and the remainder consists of cropping or improved pasture (**Table 5)**.

Table 5: Land use within the study area

Land use	Total area mapped (ha)
Cleared	1,394.64
Creek Bed	148.35
Dam	99.97
Grazing	
Derived Native Grassland	9,464.99
Cropping	4,970.68
Improved Pasture	3,626.83
Previous Evidence of Pasture Improvement	4,437.90
Native Vegetation	71,933.32
Total	95,076.68

3.5 Accuracy assessment

The accuracy assessment determined that the vegetation map was 89% accurate for areas within the main body of the Pilliga Forest. Accuracy of the vegetation map is expected to be lower in the north-eastern, eastern and south-eastern areas of the study area due to access limitations during survey. These areas are unlikely to contain Endangered Ecological Communities due to landscape position and soil types and furthermore are consolidated into a single Biometric Vegetation Type which reduces limitations for assessment in the Environmental Impact Statement (**Figure 4**). As such the impact of lower accuracy in these areas is expected to be negligible.

Given the scale of the vegetation map (1:10,000), an accuracy rating of 89% for the vegetation map is reliable and the map is therefore considered 'fit for purpose'.

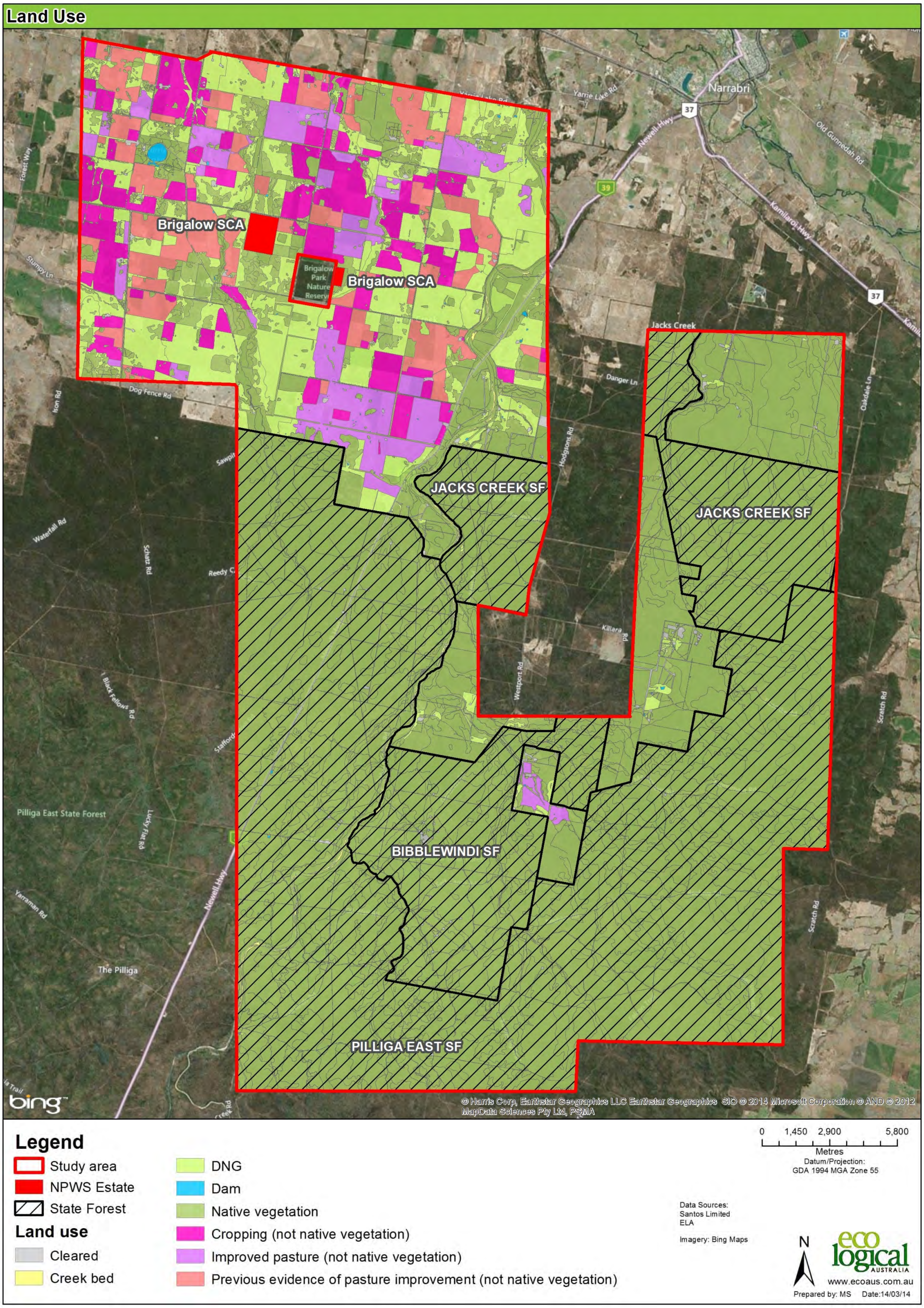

Figure 6: Land Use

4 Considerations and application

This project mapped Plant Community Types, Endangered Ecological Communities, classified land use and attributed Biometric Vegetation Types to vegetation within the study area. The scale and accuracy of the resultant mapping products will improve the proponents' ability to avoid and minimise impacts on significant ecological values throughout the planning process. The mapping products which accompany this technical report can be reliably used to determine the Plant Community Type, Endangered Ecological Community, Biometric Vegetation Type or land use at a given point in the study area.

A combination of field vegetation surveys, aerial photographs, Canopy Height Model, contour and drainage layers, soil colour and texture, previous vegetation mapping, as well as field and desktop validation has been utilised to map the vegetation of the study area as accurately as possible. Biometric Vegetation Types have been attributed for use in the assessment and in the determination of suitable offsets for the Narrabri Gas Project.

Mapping issues associated with the structural, floristic and/or landscape position similarities between vegetation types are listed in **Appendix B**. Limitations associated with the data are provided in **Appendix A**.

4.1 Assumptions and limitations

- Vegetation communities are dynamic and there is often no clearly definable boundary between communities. Interpretation, classification and mapping of Plant Community Types within the study area is based on extensive ecological survey experience in the region. There are always likely to be difference of opinions between observers, however this map has been developed to be reliably accurate at a 1:10,000 scale. Variation from the mapped Plant Community Types should carefully consider these factors.
- Rapid vegetation validation and full floristic BioMetric vegetation plots were largely restricted to areas with access (e.g. near roads and trails). Effort was made to locate full floristic BioMetric vegetation plots at least 100 m from roads where possible and a number of plots were surveyed at considerable distance from roads (~1 km).
- Large areas of vegetation have been mapped entirely based on Aerial Photograph Interpretation, Canopy Height Model, and contour and drainage layers. There is potential that small patches of different vegetation communities may occur within larger remnants or small areas of vegetation communities not identified to date may occur. Polygons have been assigned an accuracy category between 1 and 5 to indicate the confidence of linework and/or Plant Community Type attribution.
- Fire and logging history have a significant impact on the spatial and temporal distribution of vegetation communities in the study area. Areas that had been recently burnt appeared to have a low dense shrub layer and areas of vegetation that were long unburnt or heavily logged/altered often had a tall shrub layer or a dense *Callitris* spp. (Cypress Pine) midstorey. A number of Plant Community Types within the study area vary considerably (floristically and structurally) in response to fire (Allen at al. 2010).
- Remnant patches of woodland along linear features such as roads and among a cleared and altered landscape were difficult to divide and to assign Plant Community Types where there were no rapid vegetation validation points available. These patches were assigned Plant Community Types based on adjoining vegetation as well as proximity to drainage lines.

- Some areas of Derived Native Grassland were difficult to differentiate between Derived Native Grassland and previously pasture improved in a state of ‘recovery’, in which case there were allocated to Derived Native Grassland. This is likely to have overestimated the total amount of Derived Native Grassland within the study area.

5 References

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Schlencker Mapping 2010, *LiDAR Report for: Eastern Star Gas*, Eastern Star Gas Narrabri Project

Appendix A Data utilised in vegetation mapping

Data	Year	Provided by	Details	Limitations
Previous Vegetation Mapping				
Forest Types of the NSW Cypress Pine Zone (Lindsay 1967)	1967	Forestry Corporation of NSW	Forest Types is the only vegetation map available that covers the State Forests of the Pilliga and is considered to be reasonably accurate at a regional scale (e.g. 1:50,000). The purpose of the Forest Types Mapping was primarily to identify areas of *Callitris glaucophylla* (White Cypress Pine) and other commercial forestry species (Lindsay 1967).	Forest Types mapping is accurate at a regional scale only (1:50, 000). The boundary of Plant Community Types, as identified by rapid vegetation validation and Aerial Photograph Interpretation, often conflicted with this mapping layer. The Forest Types mapping recognises the dominant tree species only, with a particular focus on commercial forestry species. Forest Types mapping did not cover the entire study area.
Namoi Catchment Management Authority Regional Vegetation Community	2009	Eco Logical Australia	The Namoi Catchment Management Authority Regional Vegetation Class Mapping (ELA 2009) was compiled from a number of mapping datasets (including Forest Types), each captured at different scales and using differing methodologies. It also attempts to capture the pre-1750 extent of vegetation in the catchment. Additionally, the Namoi Catchment Management Authority Regional Vegetation Class mapping uses Regional Vegetation Classes, which is a broader classification system than the Plant Community Types of the NSW Vegetation Classification Assessment.	Regional Vegetation Classes are too broad for the assignment of Plant Community Types, although this mapping layer was useful as a guide in areas that had no other mapping layers available.

Imagery				
Light Detection and Ranging imagery	2010, 2013	Schlencker Mapping 2010; RPS Group 2013	Data acquisition using Airborne Laser Scanning techniques is used to gather Light Detection and Ranging data. The initial capture was undertaken for an area of approximately 893 km^2 between December 20 and 22, 2010. The secondary capture was undertaken for an area of approximately 1,200 km^2 for the study area between December 20 and 22, 2013. Data was provided on a square 1 km by 1 km tile grid.	The appearance of Light Detection and Ranging image tiles in 2010 (Schlencker Mapping 2010) varied considerably from that of 2013 (RPS Group 2013). Imagery from 2013 had some distortion, cloud clover and varied in colour or appearance which made Aerial Photograph Interpretation difficult in these areas.
Additional data				
Canopy Height Model	2010, 2013	Schlencker Mapping 2010; RPS Group 2013	A vegetation Canopy Height Model was developed based on the Light Detection and Ranging information captured. The Canopy Height Model was classified into 5 height range classes that were assigned a red to green colour transition. Areas with taller canopy heights were assigned to the green spectrum, while low open areas were assigned to the red spectrum.	Low dense shrub cover was difficult to distinguish in the Canopy Height Model in areas with a dense *Acacia* spp. midstorey, or in areas with a dense canopy Fire history has created distinct patterns in the imagery which appear to represent unique vegetation communities, however survey have shown many of these areas represent regeneration with dense shrub layers. Differences in processing of Canopy Height Model data from 2010 and 2013 made it difficult to 'edge-match' datasets and may have resulted in slightly different interpretations of the data.
Tracks and Trails	2009	Eastern Star Gas	The tracks and trails layer is a vector line feature of identified roads and trails within the study area, including sealed and unsealed roads and tracks in a range of conditions.	Not all tracks were identified in this layer. A number of trails within the forested area not identified in this layer may not be excluded from the vegetation mapping as they were unclear, e.g. canopy cover was high over the trail, or there was significant regrowth.

Contours	2010, 2013	Schlencker Mapping 2010 RPS Group 2013	1m and 0.5m Contours	The 2013 dataset was large and difficult to utilise for vegetation mapping due to processor requirements.
Drainage	2011	Eco Logical Australia	ArcHydro was used to develop vector line feature of drainage lines. Base information was initially sourced from 1:50,000 topographic data as well as later derived with the arc-hydro extension of ArcGIS using a Digital Elevation Model (DEM) with a 2.5m cell size originating from 1m Light Detection and Ranging derived contours. The resultant dataset was then manually edited to clean up data inconsistencies using base imagery.	The drainage layer includes high-order overland flow paths which do not correlate well with vegetation communities.

Appendix B Issues and assumptions for specific Plant Community Types

NSWVCA PCT	Issues	Assumptions and application
ID202 – Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South and Nandewar Bioregions	Within the study area, ID202 occurs on alluvial and colluvial sandy loam soils that line Bohena Creek and a number of its tributaries (Allen et al. 2010). It most often occurs in relatively small patches amongst plant community type ID401; as such it was difficult to locate isolated patches of ID202.	Patches of ID202 have been mapped in all areas, having been identified via rapid vegetation validation and/or vegetation survey plots. *Eucalyptus conica* (Fuzzy Box) is sometimes visible as it has a dull green canopy signal which contrasts to the canopy dominants of ID401 and ID399 - *Angophora floribunda* (Rough-barked Apple), *Eucalyptus blakelyi* (Red Gum) and *Eucalyptus chloroclada* (Dirty Gum) – and a number of non-validated vegetation patches were also mapped as ID202. It is likely that there are additional patches of ID202 in areas that have not been accessed.
ID399 – Red gum – Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion ID401 – Rough-barked Apple – red gum- cypress pine woodland on sandy slats, mainly in the Pilliga Scrub region	ID399 and ID401 generally occur adjacent to one another and intergrade along riparian corridors; ID399 is a riparian woodland that occurs on deep siliceous alluvial sand and loamy sand soils derived from sandstone in the stream beds, benches and banks, and ID401 is an open woodland that occurs on clayey sand or sandy clay loam soils derived from sandstone on valley flats in low hill rise landscapes (Benson 2006). These communities are relatively similar and it was often difficult to delineate the boundary between these two communities, particularly because ID399 is often a relatively thin strip of vegetation along drainage lines.	ID399 was predominantly mapped based on contours (where available). A tea tree shrub layer was often identified which assisted in the accuracy of the linework.

NSWVCA PCT	Issues	Assumptions and application
88 – Pilliga Box – White Cypress Pine – Buloke shrubby woodland in the Brigalow Belt South Bioregion 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 BBS Bioregion	ID88 and ID398 co-occur and intergrade in the north western section of the study area (within the Pilliga Forest). These two communities are difficult to decipher via Aerial Photograph Interpretation due to the following factors (Allen et al. 2010; Benson 2006): • The dominate Eucalypt species varies between the two Plant Community Types, however they are both usually dominated by *Callitris glaucophylla* (White Cypress Pine) and *Allocasuarina luehmannii* (Buloke) in the midstorey. • The dominant tree species of each community (*Eucalyptus crebra* (Narrow-leaved Ironbark) and *Eucalyptus pilligaensis* (Pilliga Box) can co-occur in both Plant Community Types. • Structurally they are similar; they both occur as a tall woodland and/or a tall open forest. • Both Plant Community Types can occur on loam soil types; ID 88 occurs on loam soils and ID 398 occurs on sandy loam soils derived from sandstone and associated alluvial or colluvial deposits.	The dominant species of ID88, Pilliga Box, has a slightly greyer canopy signal compared to the dominant of ID398, Narrow-leaved Ironbark. Patches of ID88 were sometimes distinguishable based on the colouration of the vegetation. However, the boundary between these two Plant Community Types was sometimes difficult to delineate based on Aerial Photograph Interpretation along in areas where there were no vegetation points nearby. In these areas, Forestry Types mapping was used as a guide to delineate boundaries between these two communities. ID398 is the most extensive Plant Community Type of these two communities and was therefore assigned more often than ID88. As a result, small patches of ID88 may have been overlooked in the north western section of the study area during the mapping process.
ID404 – Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soils in the Pilliga Forests ID405 – White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	Plant Community Types ID404, ID405 and ID406 co-occur in the eastern, north eastern and south eastern areas of the study area and were sometimes difficult to distinguish for the following reasons (Allen et al. 2010; Benson 2006): • These floristically similar communities contain a large range of shrub species that vary in their distribution and abundance over the extent of the Pilliga Forests. • The dominant species are a combination of the same two species (*Corymbia trachyphloia* (White Bloodwood)	Based on the description of ID406 (Allen et al. 2010; Benson 2006), as well as the location of vegetation assessments, ID406 was assigned to hillcrests where a rocky outcrop was visible and to the highest hillcrests in the eastern and south-eastern sections of the study area. Plant community type ID404 is the most extensive community in the north-eastern and eastern sections of the Narrabri Gas Project. ID404 was attributed to vegetation on hillslopes and hillcrests in low hill landscapes where the vegetation type was

NSWVCA PCT	Issues	Assumptions and application
ID406 – White Bloodwood – Motherumbah – Red Ironbark shrubby sandstone hill woodland/ open forest mainly in east Pilliga Forests.	and *Eucalyptus fibrosa* (Red Ironbark)) in all three Plant Community Types, and the density of *Acacia* species in the midstorey can vary. • These Plant Community Types are subject to intense wildfire that alters the floristic composition and vegetation structure – with successional stages of recovery comprising a changing species assemblage or dominants. Additionally, the shrub density of ID404 also depends on soil variation. • They can occur on similar landforms: - ID404 occurs on hillcrests, hillslopes or flats in rises or low hills landscape patterns - ID405 occurs on hillslopes, hillcrests in low hill landform patterns - ID406 occurs on hillcrests and upper hillslopes, some of which are rocky outcrops, in low hill and hill landscape patterns. However, ID406 is more restricted in distribution than 405 (Allen et al. 2010). • All three Plant Community Types occur on loamy sand soils derived from sandstone (although they differ in soil colour) Additionally, fewer vegetation survey plots and rapid vegetation validation have been undertaken in this area due to access limitations.	unclear, such as on hillslopes where there was a dense *Acacia* midstorey or where the dominant canopy species was unknown. ID405 predominantly occurs in the south and south-eastern sections of the study area and is generally visible in the Canopy Height Model. Areas of ID404 in low hill landscapes that had been recently burnt may have been mapped as ID405 in the south and south-eastern section of the study area. Additionally, ID404 is structurally variable and can have a dense shrub layer which may also have been mapped as ID405 in this area and in the north-east of the study area. Consequentially, the distribution and extent of these three Plant Community Types as represented in the vegetation map may be erroneous in areas that were not validated, or in areas that had been recently burnt.

NSWVCA PCT	Issues	Assumptions and application
ID404 – Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soils in the Pilliga Forests ID405 – White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions ID406 – White Bloodwood – Motherumbah – Red Ironbark shrubby sandstone hill woodland/ open forest mainly in east Pilliga Forests 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 BBS Bioregion	ID404, ID405, ID406 and ID398 are dominated or co-dominated by ironbark species and are sometimes difficult to delineate in the areas where they overlap in the north-eastern, eastern and south-eastern sections of the study area.	ID398 generally occurs on flats on sandy loam soils (Allen et al. 2010) and was not recorded during the vegetation assessments on the higher elevations in the far eastern portion of the study area. Therefore, in the north-eastern and eastern regions of the study area the distribution and boundary of ID398 was primarily mapped based on the contours, in conjunction with available vegetation assessments. In the south-eastern section of the study area, ID398 was also distinguished from ID405 primarily based on contours, as well as the Canopy Height Model. A higher number of vegetation assessments were also undertaken in this area. Additionally, ID404, ID405, ID406 generally have a greener canopy signal in the aerial imagery due to the typical composition of the understorey species, whereas ID398 is dominated by White Cypress Pine and Buloke in the midstorey which gives it a dull green appearance.
ID405 – White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions ID408 - Dirty Gum (Baradine Gum) -	ID405, ID408, and ID40X overlap in extent in the central, southern and north eastern regions of the study area. ID379 co-occurs with these communities in the southern section of the study area only. These communities were sometimes difficult to distinguish for the following reasons (Allen et al. 2010; Benson 2006):	In areas where there were no available vegetation assessment points, the allocation of Plant Community Types was primarily based on the position within the study area, as well as on the proximity to accurately assigned polygons. ID40X primarily occurs along Bohena Creek and its tributaries on deep sand; ID405 primarily occurs on the alluvial outwash to the south and

NSWVCA PCT	Issues	Assumptions and application
Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region ID40x – White Bloodwood - Dirty Gum (Baradine Gum) - Rough-barked Apple- Black Cypress Pine - open heath on deep sand ID379 – Inland Scribbly Gum – White Bloodwood – Red Stringybark – Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP – Pillige region in the BBS Bioregion	• Structurally they are all mid-high to tall woodlands with a sparse to mid-dense shrub layer. ID40X, ID379 and ID405 often have a dense shrub layer after fire. • They can occur on similar substrates: - ID405 occurs on yellow to orange loamy sand soils that are derived from sandstone. - ID40X occurs on deep yellow, orange, red or brown sand to loamy sand soils. - ID408 occurs on light to dark often shallow brown loamy sand soils. - ID379 occurs on shallow orange, yellow to brown loamy sand – clay soils. • ID405 and ID408 occur on hillslopes and hillcrests in low hill landscapes. ID379 occurs on mid-slopes, below sandstone scarps in low hills and hills. ID40X occurs on deep alluvial/colluvial sand deposits. • Fire intensity and time since fire alters the structure and appearance of these communities. • The density of *Callitris endlicheri* (Black Cypress Pine) in these communities sometimes confuses Aerial Photograph Interpretation and the Canopy Height Model. ID379, ID40X, and ID405 were particularly difficult to distinguish in the southern alluvial outwash to the south of the study area, particularly areas that had been recently burnt or had dense Cypress regrowth.	south west as well as between drainage channels in the north-east of the study area; and ID408 primarily occurs in the central and north-eastern regions of the study area on shallow soils.

NSWVCA PCT	Issues	Assumptions and application
ID40x – White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests ID408 - Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	ID40X was originally assigned the Plant Community Type ID408 as floristically and structurally this Plant Community Type was the most suited to this community; however, a more appropriate representation of this community was discovered in the more recently surveyed eastern portion of the study area. While floristically and structurally similar, ID408 has a sparser shrub layer and is dominated by *Eucalyptus chloroclada* (Dirty Gum), and ID40X is usually dominated by either White Bloodwood, Dirty Gum or Rough-barked Apple and has a moderate to dense heathy shrub layer. ID408 occurs on shallow brown loamy sand soils while ID40X occurs on deep yellow brown sandy to loamy sand soils. These communities overlap in distribution towards the centre and north east of the study area and were sometimes difficult to distinguish due to the re-classification of ID40X and resultant inconsistencies with vegetation assessment points.	Where available, rapid vegetation validation and full floristic BioMetric vegetation plots were used to assign Plant Community Types. However, where the floristic composition was unidentified in the rapid vegetation validation and where the Plant Community Type was unclear using Aerial Photograph Interpretation and the available data sets, the Plant Community Type was assigned based on the proximity to accurately assigned polygons and on the location within the study area. ID408 primarily occurs towards the north-east and east of the study area on shallower loamy sand soils and ID40X predominantly occurs in the western portion of the study area on deeper loamy sand soils along Bohena Creek and its tributaries.
ID256 – Green Mallee tall mallee woodland on rises in the Pilliga – Goonoo regions, southern BBS Bioregion	ID256 occurs on sandy clay loam, often quarts gravelly soils on rises and low hills. It is restricted in extent (Benson 2006). Only one small occurrence of ID256 was intersected during field surveys. As such, there is limited knowledge on the distribution and extent of this community and deciphering the occurrence based on Aerial Photograph Interpretation alone was difficult, particularly because it occurred amongst ID404 which often has a dense midstorey of Acacia which resembles *Eucalyptus viridis* (Green Mallee) in colour.	It is likely that there are small unmapped patches of ID256 in the eastern section of the study area.

NSWVCA PCT	Issues	Assumptions and application
Derived Native Grassland	Large areas of Derived Native Grassland were not validated due to accessibility and so in some cases it was very difficult to assign parent communities to Derived Native Grassland based on Aerial Photograph Interpretation only, especially when it was highly disturbed. Derived Native Grassland was assigned a Plant Community Type based largely on the adjacent vegetation. This classification may not accurately represent what originally occurred in these areas prior to alteration and clearing/thinning, however without a canopy or understorey it is difficult to accurately assign the Plant Community Type.	Derived Native Grassland was assigned a Plant Community Type based on the plant community assigned to the adjacent vegetation remnant. Proximity to drainage lines and the Namoi Catchment Management Authority's Regional Vegetation Class Mapping was also considered.

Appendix C Plant Community Types recorded in the study area

Plant Comm. ID	Common name	Dominant species
27	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	*Acacia pendula / Rhagodia spinescens - Sclerolaena muricata s.l. / Monachather paradoxus - Chloris truncata - Dichanthium sericeum* subsp. *sericeum - Leiocarpa tomentosa*
35	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	*Acacia harpophylla - Casuarina cristata / Geijera parviflora - Eremophila mitchellii - Rhagodia spinescens -Apophyllum anomalum / Einadia nutans* subsp. *eremaea - Oxalis chnoodes - Austrostipa ramosissima – Enteropogon acicularis*
55	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	*Casuarina cristata / Geijera parviflora - Alectryon oleifolius* subsp. *canescens - Eremophila mitchellii – Capparis mitchellii / Einadia nutans* subsp. *nutans - Enchylaena tomentosa - Monachather paradoxus - Sclerolaena birchii*
78	River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	*Eucalyptus camaldulensis - Casuarina cunninghamiana / Callistemon sieberi - Leptospermum polygalifolium s.l. - / Cynodon dactylon - Austrostipa verticillata - Alternanthera denticulata - Commelina cyanea*
88	Pilliga Box - White Cypress	*Eucalyptus pilligaensis - Callitris glaucophylla - Eucalyptus populnea* subsp. *bimbil - Allocasuarina luehmannii / Eremophila*

Plant Comm. ID	Common name	Dominant species
	Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	*mitchellii - Acacia deanei* subsp. *paucijuga - Maireana microphylla - Dodonaea viscosa* subsp. *Angustifolia / Einadia nutans* subsp. *linifolia - Aristida ramosa - Boerhavia dominii - Rostellularia adscendens* subsp. *adscendens*
141	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	*Melaleuca uncinata - Acacia burrowii / Calytrix tetragona - Westringia cheelii - Acacia triptera - Cryptandra amara* var. *amara / Actinotus gibbonsii - Aristida jerichoensis* var. *jerichoensis - Thysanotus tuberosus* subsp. *tuberosus -Gnephosis tenuissima*
202	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions	*Eucalyptus conica - Eucalyptus blakelyi - Eucalyptus melliodora - Callitris glaucophylla / Acacia deanei* subsp. *paucijuga - Geijera parviflora - Dodonaea viscosa* subsp. *spatulata / Austrostipa verticillata - Dichondra repens -Boerhavia dominii - Elymus scaber* var. *scaber*
256	Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern BBS Bioeregion	*Eucalyptus viridis - Callitris endlicheri / Dodonaea viscosa* subsp. *cuneata - Melichrus urceolatus - Cassinia arcuata - Acacia hakeoides / Austrodanthonia fulva - Cheilanthes sieberi* subsp. *sieberi - Dianella revoluta* var. *revoluta -Goodenia hederacea* subsp. *hederacea*
379	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion	*Eucalyptus rossii - Corymbia trachyphloia* subsp. *amphistomatica - Callitris endlicheri - Eucalyptus macrorhyncha / Bossiaea rhombifolia* subsp. *rhombifolia - Melichrus erubescens - Persoonia cuspidifera - Cassinia quinquefaria / Joycea pallida - Pomax umbellata - Dichelachne micrantha - Lomandra filiformis* subsp. *filiformis*
397	Poplar Box - White Cypress	*Eucalyptus populnea* subsp. *bimbil - Callitris glaucophylla - Atalaya hemiglauca - Allocasuarina luehmannii / Geijera*

Plant Comm. ID	Common name	Dominant species
	Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	*parviflora - Psydrax oleifolia - Acacia deanei* subsp. *paucijuga - Dodonaea viscosa* subsp. *spatulata / Sclerolaena diacantha - Chenopodium desertorum* subsp. *microphyllum - Austrostipa scabra* subsp. *scabra - Aristida ramosa*
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 BBS Bioregion	*Eucalyptus crebra - Callitris glaucophylla - Allocasuarina luehmannii - Eucalyptus chloroclada / Melichrus urceolatus - Acacia deanei* subsp. *paucijuga - Cassinia arcuata - Acacia spectabilis / Austrostipa scabra* subsp. *scabra – Cyperus gracilis -Calotis cuneifolia - Eragrostis lacunaria*
399	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	*Eucalyptus blakely - Eucalyptus camaldulensis* <-> *chloroclada intergrade - Angophora floribunda – Callitris glaucophylla / Leptospermum polygalifolium* subsp. *transmontanum - Acacia deanei* subsp. *paucijuga – Acacia penninervis* var. *penninervis - Callistemon linearis / Arundinella nepalensis - Juncus continuus - Cyperus lucidus -Alternanthera denticulate*
401	Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	*Angophora floribunda - Eucalyptus blakelyi - Callitris endlicheri - Eucalyptus chloroclada / Hibbertia obtusifolia -Cassinia arcuata - Acacia spectabilis - Brachyloma daphnoides* subsp. *pubescens / Lomandra longifolia – Arundinella nepalensis - Imperata cylindrica* var. *major - Ajuga australis*
402	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	*Eucalyptus sideroxylon - Callitris glaucophylla - Allocasuarina luehmannii / Acacia deanei* subsp. *paucijuga – Acacia spectabilis / Aristida vagans - Cymbopogon refractus - Lomandra longifolia - Dianella revoluta* var. *revoluta*

Plant Comm. ID	Common name	Dominant species
404	Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	*Eucalyptus fibrosa - Corymbia trachyphloia* subsp. *amphistomatica - Callitris glaucophylla - Eucalyptus viridis / Acacia burrowii - Phebalium squamulosum* subsp. *gracile - Homoranthus flavescens - Cryptandra amara* var. *floribunda / Gonocarpus elatus - Goodenia rotundifolia - Thyridolepis mitchelliana - Schoenus kennyi*
405	White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	*Corymbia trachyphloia* subsp. *amphistomatica - Eucalyptus fibrosa - Callitris endlicheri - Eucalyptus crebra / Persoonia sericea - Hibbertia obtusifolia - Grevillea floribunda - Xanthorrhoea acaulis / Pomax umbellata - Aristida jerichoensis* var. *subspinulifera - Digitaria breviglumis - Schoenus ericetorum*
406	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	*Corymbia trachyphloia* subsp. *amphistomatica - Acacia cheelii - Eucalyptus fibrosa - Callitris endlicheri / Homoranthus flavescens - Philotheca salsolifolia* subsp. *salsolifolia - Harmogia densifolia - Persoonia sericea / Cleistochloa rigida - Digitaria breviglumis - Goodenia rotundifolia - Stypandra glauca*
408	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	*Eucalyptus chloroclada - Callitris endlicheri - Eucalyptus crebra - Acacia cheelii / Brachyloma daphnoides* subsp. *pubescens - Phebalium squamulosum* subsp. *squamulosum - Homoranthus flavescens - Cassinia arcuata / Aristida calycina - Goodenia hederacea* subsp. *hederacea - Pomax umbellata - Cheilanthes sieberi* subsp. *sieberi*
418	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	*Callitris glaucophylla - Eucalyptus melanophloia - Eucalyptus blakelyi - Eucalyptus albens / Geijera parviflora - Pimelea neo-anglica - Maireana microphylla - Notelaea microcarpa* var. *microcarpa / Aristida personata – Einadia nutans - Rostellularia adscendens* subsp. *adscendens - Brunoniella australis*

Plant Comm. ID	Common name	Dominant species
425	Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	*Eucalyptus fibrosa - Eucalyptus nubila - Callitris endlicheri / Acacia triptera - Calytrix tetragona - Grevillea floribunda - Harmogia densifolia / Lomandra filiformis subsp. filiformis - Lepidosperma laterale - Gahnia aspera - Schoenus ericetorum*
428	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	*Corymbia tessellaris - Callitris glaucophylla - Acacia leiocalyx* subsp. *leiocalyx - Eucalyptus albens / Pimelea microcephala* subsp. *microcephala - Notelaea microcarpa* var. *microcarpa - Pittosporum angustifolium – Dodonaea viscosa* subsp. *angustifolia / Aristida vagans - Vittadinia dissecta* var. *hirta - Cyperus gracilis - Cheilanthes distans*
ID40X	White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests	*Corymbia trachyphloia* subsp. *amphistomatica – Eucalyptus chloroclada – Angophora floribunda – Eucalyptus macrorhyncha - Callitris endlicheri / Persoonia sericea - Hibbertia obtusifolia - Grevillea floribunda - Xanthorrhoea acaulis / Pomax umbellata - Aristida jerichoensis* var. *subspinulifera - Digitaria breviglumis - Schoenus ericetorum*

Appendix D Plant Community Types, Regional Vegetation Classes and Biometric Vegetation Type classification

NSWVCA PCT ID	NSWVCA PCT description	RVC ID	RVC classes description	BVT ID	BVT description
27	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	75	Weeping Myall open woodland, Darling Riverine Plains, Brigalow Belt South and Nandewar	NA219	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions (Benson 27)
35	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	79	Brigalow - Belah woodland on alluvial clay soil, mainly Brigalow Belt South	NA117	Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion (Benson 35)
35	Derived Native Grassland	79	Brigalow - Belah woodland on alluvial clay soil, mainly Brigalow Belt South	NA117	Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion (Benson 35)
55	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	76	Coolibah - Poplar Box - Belah woodlands on floodplains, mainly Darling Riverine Plains and Brigalow Belt South	NA102	Belah woodland on alluvial plains in central-north NSW (Benson 55)
78	River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	73	River Red Gum riverine woodlands and forests, Darling Riverine Plains, Brigalow Belt South and Nandewar	NA193	River Red Gum riverine woodlands and forests in the Nandewar and Brigalow Belt South Bioregions (Benson 78)
88	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	32	Pilliga Box - Poplar Box - White Cypress Pine shrub/grass woodland on sandy loams, Darling Riverine Plains and Brigalow Belt South	NA179	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)

NSWVCA PCT ID	NSWVCA PCT description	RVC ID	RVC classes description	BVT ID	BVT description
88	Derived Native Grassland	32	Pilliga Box - Poplar Box - White Cypress Pine shrub/grass woodland on sandy loams, Darling Riverine Plains and Brigalow Belt South	NA179	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)
141	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	31	Broombush shrubland of the sand plains of the Pilliga region, Brigalow Belt South	NA121	Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (Benson 141)
202	Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion	17	Box - gum grassy woodlands, Brigalow Belt South and Nandewar	NA141	Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (Benson 202)
202	Derived Native Grassland	17	Box - gum grassy woodlands, Brigalow Belt South and Nandewar	NA141	Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (Benson 202)
256	Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion	58	Shrubby woodlands or mallee woodlands on stoney soils, Brigalow Belt South and Nandewar	NA143	Green Mallee scrub on sandstone rises in the Brigalow Belt South Bioregion (Benson 179)
379	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
397	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	32	Pilliga Box - Poplar Box - White Cypress Pine shrub/grass woodland on sandy loams, Darling Riverine Plains and Brigalow Belt South	NA179	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)
398	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats in	33	Ironbark – White Cypress Pine – Bulloak shrubby woodlands mainly of	NA227	White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the

NSWVCA PCT ID	NSWVCA PCT description	RVC ID	RVC classes description	BVT ID	BVT description
	the Pilliga Scrub and surrounding forests in the central north BBS Bioregion		the Pilliga outwash area, Brigalow Belt South		Brigalow Belt South Bioregion
398	Derived Native Grassland	33	Ironbark – White Cypress Pine – Bulloak shrubby woodlands mainly of the Pilliga outwash area, Brigalow Belt South	NA227	White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion
399	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	96	Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South	NA197	Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion
401	Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	96	Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South	NA197	Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion
401	Derived Native Grassland	96	Blakely's Red Gum riparian woodland of the Pilliga Outwash, Brigalow Belt South	NA197	Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion
402	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	33	Ironbark – White Cypress Pine – Bulloak shrubby woodlands mainly of the Pilliga outwash area, Brigalow Belt South	NA160	Mugga Ironbark - Pilliga Box - pine-Bulloak shrubby woodland on Jurassic Sandstone of outwash plains (Benson 255)
404	Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
405	White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion

NSWVCA PCT ID	NSWVCA PCT description	RVC ID	RVC classes description	BVT ID	BVT description
406	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
408	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
408	Derived Native Grassland	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
418	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	44	White Box - pine - Silver-leaved Ironbark shrubby open forests, Brigalow Belt South and Nandewar	NA179	Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)
425	Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	31	Broombush shrubland of the sand plains of the Pilliga region, Brigalow Belt South	NA121	Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (Benson 141)
428	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	85	Carbeen woodland on alluvial soils, Darling Riverine Plains and Brigalow Belt South	NA126	Carbeen woodland on alluvial soils (Benson 71)
40X	White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion
40X	Derived Native Grassland	56	Ironbark - White Bloodwood - Black Cypress Pine heathy woodlands, Brigalow Belt South	NA124	Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion

Appendix E Plant Community Types in the study area by area and condition

Table 6: Plant Community Types mapped within the study area

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
27	*Acacia pendula* (Weeping Myall) open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	Derived Native Grassland	Low	0
			Moderate	173.3
			Good	0
			Total	173.3
		Native vegetation	Low (TSC Act)	0.47
			Low (EPBC Act)	1.23
			Moderate (TSC Act)	2.2
			Moderate (EPBC Act)	15.9
			Good (TSC Act)	0.8
			Good (EPBC Act)	15.4
			Total	36.0
35	*Acacia harpophylla* (Brigalow) – *Casuarina cristata* (Belah) open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	Derived Native Grassland	Low	968.5
			Moderate	2,325.6
			Good	933.0
			Total	4,227.2
		Native Vegetation	Low (TSC Act)	5.3
			Low (EPBC Act)	504.5
			Moderate (TSC Act)	6.5
			Moderate (EPBC Act)	716.1
			Good (TSC Act)	8.8
			Good (EPBC Act)	1,226.7
			Total	2,468.0
55	*Casuarina cristata* (Belah) woodland on alluvial plains and	Derived Native Grassland	Low	146.1
			Moderate	174.0

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
	low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions		Good	0
			Total	320.4
		Native Vegetation	Low	82.7
			Moderate	140.5
			Good	135.7
			Total	358.9
78	*Eucalyptus camaldulensis* (River Red Gum) riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	Native Vegetation	Low	2.4
			Moderate	0
			Good	8.1
			Total	10.5
88	*Eucalyptus pilligaensis* (Pilliga Box) - *Callitris glaucophylla* (White Cypress Pine) - *Allocasuarina luehmannii* (Buloke) shrubby woodland in the Brigalow Belt South Bioregion	Derived Native Grassland	Low	254.2
			Moderate	1,144.4
			Good	120.0
			Total	1,518.5
		Native Vegetation	Low	199.4
			Moderate	632.6
			Good	3,596.1
			Total	4,428.1
141	*Melaleuca uncinata* (Broombush) - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	Native Vegetation	Low	0
			Moderate	10.0
			Good	1,024.8
			Total	1,034.8
202	*Eucalyptus conica* (Fuzzy Box) woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions	Derived Native Grassland	Low	0
			Moderate	1.1
			Good	0.3
			Total	1.4
		Native Vegetation	Low	4.0
			Moderate	2.9
			Good	581.5
			Total	588.4
256	*Eucalyptus viridis* (Green Mallee)	Native Vegetation	Low	0

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
	tall mallee woodland on rises in the Pilliga - Goonoo regions, southern BBS Bioeregion		Moderate	0
			Good	20.3
			Total	20.3
379	*Eucalyptus rossii* (Inland Scribbly Gum) - *Corymbia trachyphloia* (White Bloodwood) – *Eucalyptus macrorhyncha* (Red Stringybark) – *Eucalyptus endlicheri* (Black Cypress Pine) shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion	Native Vegetation	Low	0
			Moderate	0
			Good	103.6
			Total	103.6
397	*Eucalyptus populnea* subsp. *Bimbil* (Poplar Box) – *Callitris glaucophylla* (White Cypress Pine) shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	Derived Native Grassland	Low	119.6
			Moderate	210.5
			Good	115.8
			Total	445.9
		Native Vegetation	Low	70.6
			Moderate	173.3
			Good	73.1
			Total	317.0
398	*Eucalyptus crebra* (Narrow-leaved Ironbark) – *Callitris glaucophylla* (White Cypress Pine) - *Allocasuarina luehmannii* (Buloke tall) open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north BBS Bioregion	Derived Native Grassland	Low	46.3
			Moderate	371.4
			Good	77.2
			Total	494.9
		Native Vegetation	Low	29.4
			Moderate	2,719.6
			Good	20,731.4
			Total	23,480.0
399	*Eucalyptus blakelyi*) (red gum) - *Angophora floribunda* (Rough-barked Apple) +/- *Leptospermum polygalifolium* (tea tree) sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone	Derived Native Grassland	Low	0
			Moderate	44.9
			Good	2.2
			Total	47.1
		Native vegetation	Low	0.4

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
	forests, BBS Bioregion		Moderate	171.7
			Good	874.3
			Total	1,046.4
401	*Angophora floribunda* (Rough-barked Apple) - *Eucalyptus blakelyi* and *Eucalyptus chloroclada* (red gum) - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	Derived Native Grassland	Low	770.7
			Moderate	827.2
			Good	43.4
			Total	1,641.2
		Native Vegetation	Low	74.2
			Moderate	654.4
			Good	5,210.5
			Total	5,939.2
402	*Eucalyptus sideroxylon* (Mugga Ironbark) - *Callitris glaucophylla* (White Cypress Pine) - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	Derived Native Grassland	Low	8.9
			Moderate	59
			Good	115.1
			Total	183.1
		Native Vegetation	Low	52.2
			Moderate	33.7
			Good	89.2
			Total	175.1
404	*Eucalyptus fibrosa* (Red Ironbark) - *Corymbia trachyphloia* (White Bloodwood) - /+ *Acacia burrowii* (Burrows Wattle) heathy woodland on sandy soil in the Pilliga forests	Native Vegetation	Low	0
			Moderate	27.6
			Good	9,954.9
			Total	9,982.5
405	*Corymbia trachyphloia* (White Bloodwood) - *Eucalyptus fibrosa* (Red Ironbark) - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	Native Vegetation	Low	0
			Moderate	770.8
			Good	5,879.7
			Total	6,650.5
406	*Corymbia trachyphloia* (White Bloodwood) – *Acacia cheelii*	Native Vegetation	Low	0
			Moderate	62.8

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
	(Motherumbah) - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests		Good	3,169.6
			Total	3,232.4
408	*Eucalyptus chloroclada* (Dirty Gum (Baradine Gum)) – *Callitris endlicheri* (Black Cypress Pine) - *Corymbia trachyphloia* (White Bloodwood) shrubby woodland on of the Pilliga forests and surrounding region	Derived Native Grassland	Low	58.8
			Moderate	28.9
			Good	15.9
			Total	103.5
		Native Vegetation	Low	14.9
			Moderate	308.2
			Good	2,761.7
			Total	3,084.8
418	*Callitris glaucophylla* (White Cypress Pine) - *Eucalyptus melanophloia* (Silver-leaved Ironbark) - *Geijera parviflora* (Wilga shrub) grass woodland of the Narrabri-Yetman region, BBS Bioregion	Derived Native Grassland	Low	18.4
			Moderate	50.9
			Good	0
			Total	69.3
		Native Vegetation	Low	17.8
			Moderate	19.6
			Good	24.9
			Total	62.3
425	*Acacia triptera* (Spur-wing Wattle) heath on sandstone substrates in the Goonoo – Pilliga forests Brigalow Belt South Bioregion	Native Vegetation	Low	0
			Moderate	0
			Good	366.7
			Total	366.7
428	*Corymbia tessellaris* (Carbeen) - *Callitris glaucophylla* (White Cypress Pine) - *Acacia leiocalyx subsp. leiocalyx* (Curracabah) - *Eucalyptus albens* (White Box) tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	Native Vegetation	Low	0
			Moderate	0
			Good	15.0
			Total	15.0
40X	White Bloodwood – *Eucalyptus chloroclada* (Dirty Gum	Derived Native Grassland	Low	0
			Moderate	201.2

Plant Comm. ID	Common name	Landuse	Condition	Total area mapped (ha)
	(Baradine Gum)) – *Angophora floribunda* (Rough Barked Apple) – *Callitris endlicheri* (Black Cypress Pine) heathy open woodland on deep sand in the Pilliga forests		Good	38.4
			Total	239.6
		Native Vegetation	Low	0
			Moderate	1,874.9
			Good	5,657.7
			Total	7,532.6
	Other	Evidence of Pasture improvement	Total	4,437.9
		Pasture improved	Total	3,626.8
		Cropping	Total	4,970.7
		Cleared – tracks, houses and other	Total	1,394.6
		Dams	Total	100.0
		Creek bed	Total	148.4
GRAND TOTAL				**95,076.7**

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F3: Vegetation impact modelling technical report

EHS Support

Land Disturbance Probabilistic Calculation Methodology – Narrabri Gas Project

Prepared for:
Santos NSW Pty Ltd

November 2014

consider it done

Prepared by:
EHS Support LLC

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APPENDICES

ACRONYMS

%	percent
AEP	Annual Exceedance Probability
DNG	Derived Native Grassland
EIS	Environmental Impact Statement
EPBC	Environmental Protection and Biodiversity Act 1999
ESA	Ecological Sensitivity Analysis
GIS	Graphical Information Systems
GLNG	Gladstone Liquefied Natural Gas
ha	hectare
km	kilometres
km2	Square kilometres
LGA	Narrabri Local Government Area
m	metre
ML	millilitres
MNES	Matters of National Environmental Significance
NSW	New South Wales
PEL	Petroleum Exploration Licence
PL	Petroleum Lease
PoO	Plan of Operations
Santos	Santos NSW Pty Ltd
TECs	Threatened Ecological Communities
TJ	terajoules

EXECUTIVE SUMMARY

Historically disturbance limits have been calculated using methods that attempt to calculate disturbance as an ‘absolute’. The methods utilised a systematic spacing (network) of wells and infrastructure that have been overlain onto maps of terrestrial ecology to provide estimates of disturbance. This method is fraught with limitations and does not effectively consider other constraints, the viability of a resource, or logistical considerations. As a result, these estimation methods have provided major underestimates of the magnitude of disturbance, which do not reflect the dynamic and iterative nature of coal seam gas development projects.

The development of gas resources utilises a systematic program of exploration, appraisal and development. This program of exploration and appraisal continues concurrently with development activities and determines the location, intensity and schedule of development. Reflecting this framework, a probabilistic methodology has been developed for calculating potential disturbance associated with well and linear infrastructure (roads and gathering pipelines) for a range of potential development scenarios. The disturbance associated with major infrastructure is not assessed by these methods, as this infrastructure has been located and assessed in the Environmental Impact Statement (EIS).

The methodology developed in this document considers that land disturbance will be a function of well and linear infrastructure placement and that theoretically, the intensity of development (in a specific area) could vary with the development likely to involved concentrated areas of production wells. The Land Disturbance and Field Planning Protocol (the Protocol) has been developed and is designed to avoid, minimise and manage disturbance. The calculation methodology considers the exclusions and constraints outlined in the Protocol in the development of estimates of disturbance.

The method calculation method developed and discussed in this report utilises a series of steps including:

1. Development of probabilistic disturbance distributions for different densities of development relative to vegetation and habitat coverage.
2. Assessment and resolution of mapped and field data to develop a Graphical Information Systems (GIS) database of terrestrial ecological communities over the development area.
3. Integration of the probabilistic disturbance distributions into the GIS database to develop estimates of disturbance for three different intensities of development.
4. Determination of the probable development scenarios and develop of project specific disturbance estimates.

The probabilistic method of calculating disturbance distributions used a series of Monte-Carlo simulations where the infrastructure (wells and linear infrastructure) were fixed in space, and the distribution and density of terrestrial ecology was the independent variable that was varied randomly. To replicate the decision-making process associated with avoidance, a resampling strategy was utilised in the statistical assessment to evaluate changes in the probability and magnitude of the disturbance. This resampling was constrained to reflect the limits on well pad placement (the well pads must be located proximal to the resource and at sufficient distance from other gas production wells).

Using the probabilistic disturbance distributions, project specific GIS data was integrated into the models to estimate the potential disturbance associated with the theoretical development of 1, 2 and 3 wells per 1 km^2 (square kilometres) cell. Using a series of potential development scenarios, the potential development densities were determined and appropriate theoretical disturbance values per cell were multiplied by the ratio of proposed wells to available development cells.

As part of the EIS, the probabilistic estimates of disturbance for a range of development scenarios and infrastructure placement strategies involving high and moderate-high ecologically sensitive areas were qualitatively assessed to determine a maximum probable project disturbance.

The method provides a reliable estimate for maximum disturbance as it considers both the inherent uncertainties associated with the phasing of oil and gas development work and the additional constraints and considerations for development of field infrastructure. This method is robust, repeatable and transparent and is considered appropriate for the assessment of potential project impacts.

1.0 INTRODUCTION

The following report outlines the estimation methodologies utilised to calculate potential disturbances of terrestrial ecology. The methodology discussed below develops a theoretical framework and probabilistic methodology for estimation of land disturbance associated with the proposed development activities of the Narrabri Gas Project. This methodology considers the framework of avoidance strategies as well as the processes that have been successfully applied to other similar projects [e.g., the Gladstone Liquid Natural Gas Project (GLNG)].

This methodology combines an understanding of the process of gas development with probabilistic methods and validated spatial data sets to provide a clear and repeatable methodology for the development of the maximum probable disturbance associated with the planned project development. The process described below builds on the powerful Graphical Information Systems (GIS) used by The Proponent and the detailed ecological mapping (State Mapping and field-based data) to provide estimates of disturbance for a range of development scenarios. Using these scenarios and an understanding of the most probable project development, estimates of the maximum project disturbance are provided.

Key background and discussion of the methodology are provided in the sections below.

1.1 Objectives

The objective of this study was to design a robust, clear and repeatable methodology for assessment of the likely vegetation and habitat disturbance associated with gas development. This methodology was designed to assess the potential impacts of well pads and associated linear infrastructure (roads, access tracks and gathering line corridors). The developed methodology needed to allow for simplified probabilistic assumptions of disturbance which could be applied to complex GIS data and provide probable maximum magnitudes of disturbance. This methodology also needed to be flexible and provide probable disturbance distributions for a range of developments (based on differences in habitat and vegetation densities) so standard disturbance assumptions could be applied to large GIS data sets consistently.

A probabilistic estimation of maximum disturbance was utilised as:

1. The exploration and appraisal activities are ongoing and the development scenarios are not yet fixed. Probabilistic methodologies can consider a range of development scenarios that ultimately are variably distributed.
2. The inherent variability of vegetation and habitat data both spatially and temporally requires the use of probabilistic averaged disturbances to reflect the inherent uncertainties and variability within data sets.

2.0 BACKGROUND

2.1 Overview and Description of Project

The Proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri.

The Narrabri Gas Project (the project) seeks to develop and operate a gas production field, requiring the installation of gas wells, gas and water gathering systems, and supporting infrastructure. The natural gas produced would be treated at a central gas processing facility on a local rural property (Leewood), approximately 25 kilometres south-west of Narrabri. The gas would then be piped via a high-pressure gas transmission pipeline to market. This pipeline would be part of a separate approvals process and is therefore not part of this development proposal.

The proposal includes the construction and operation of a range of exploration and production activities and infrastructure including:

- Gas exploration and appraisal activities including seismic surveys, chip holes, core holes and pilot wells, associated temporary supporting infrastructure (flares or water balance tanks) and the installation of monitoring equipment. These may be converted to production wells and counted within the total maximum number of production wells proposed.
- Installation and operation of up to 850 new wells on up to 425 well pads. A single well may be vertical, deviated, or lateral; the latter may include several horizontal connections sometimes referred to as a multilateral. The target production peak rate is approximately 200 terajoules (TJ) per day. Each well pad would be approximately 100 by 100 metres (m) [(one hectare (ha)] in size during drilling and construction, reducing by over 50% during operation.
- Gas and water gathering systems (comprising underground pipelines) to link each wellhead to the gas processing facility and the water management treatment and beneficial reuse facilities. A right of way of approximately on average 10 m wide would be required during installation of the gas and water gathering systems, with an access track of 5 m during operation.
- A central gas processing facility and a central water processing facility located at the Leewood property.

2.2 Project Location

The project will be located to the south and west of Narrabri (see **Figure 1**). The project area covers about 950 square kilometres (95,000 hectares), and the project footprint would directly impact about one percent of that area.

The project area contains a portion of the region known as ‘the Pilliga’; which is an agglomeration of a forested area covering more than 500,000 hectares in north-western NSW around Coonabarabran, Baradine and Narrabri. Nearly half of the Pilliga is allocated to conservation, managed under the NSW *National Parks and Wildlife Act 1974*. The Pilliga has spiritual meaning and cultural significance for the Aboriginal people of the region.

Other parts of the Pilliga were dedicated as State forest, and set aside for the purpose of ‘forestry, recreation and mineral extraction, with a strategic aim to “provide for exploration, mining, petroleum production and extractive industry” under the *Brigalow and Nandewar Community Conservation Area Act 2005*. The parts of the project area on state land are located within this section of the Pilliga.

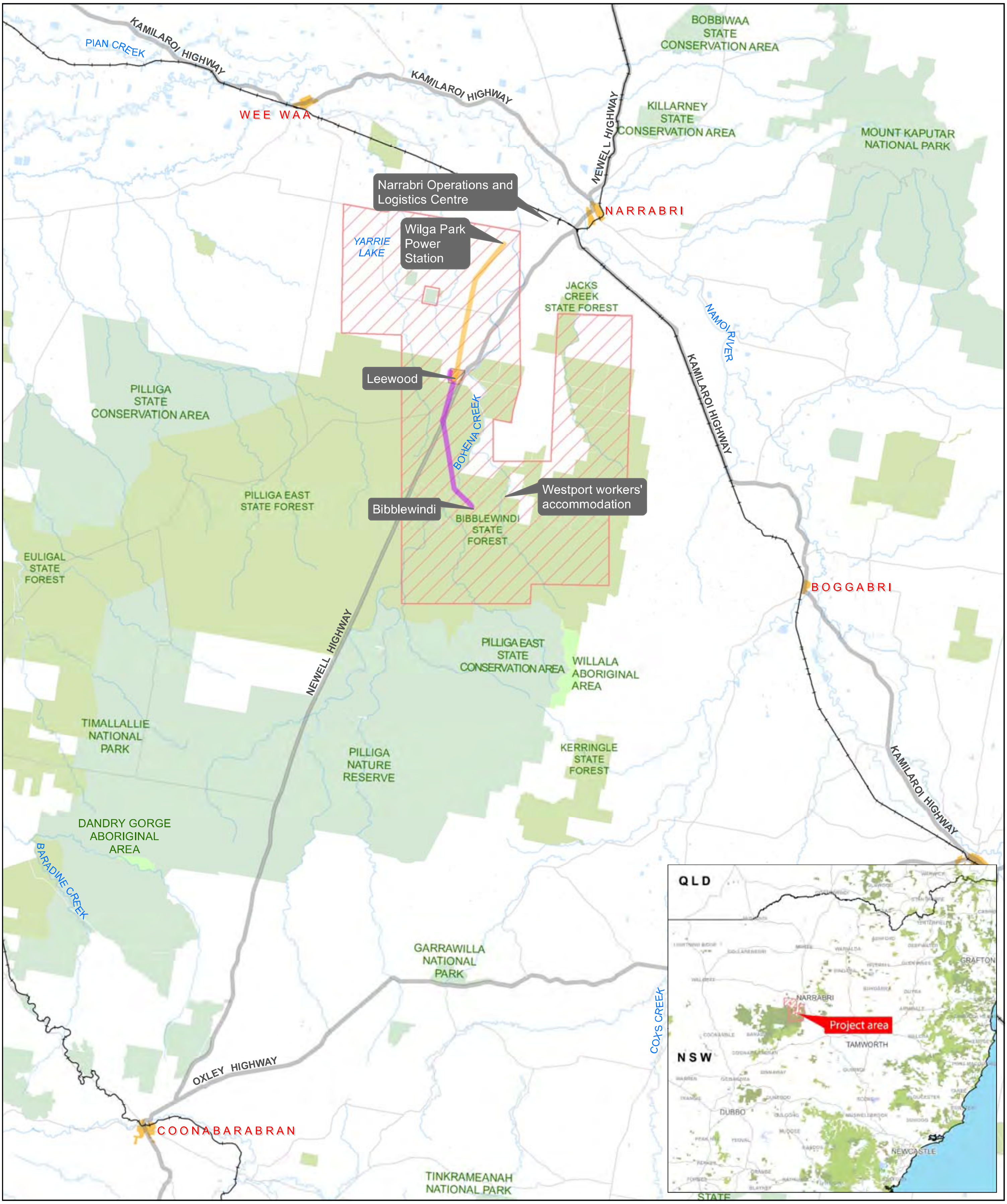
The semi-arid climate of the region and general unsuitability of the soils for agriculture have combined to protect the Pilliga from widespread clearing. Commercial timber harvesting activities in the Pilliga were preceded by unsuccessful attempts in the mid-1800s to establish a wool production industry. Resource exploration has been occurring in the area since the 1960s; initially for oil, but more recently for coal and gas.

The ecology of the Pilliga has been fragmented and otherwise impacted by commercial timber harvesting and related activities over the last century through:

- the establishment of more than 5,000 kilometres of roads, tracks and trails
- the introduction of pest species
- the occurrence of drought and wildfire.

The project area avoids the Pilliga National Park, Pilliga State Conservation Area, Pilliga Nature Reserve and Brigalow Park Nature Reserve. Brigalow State Conservation Area is within the project area but would be protected by a 50-metre surface exclusion zone.

Agriculture is a major land use within the Narrabri LGA; about half of the LGA is used for agriculture, split between cropping and grazing. Although the majority of the project area would be within State forests, much of the remaining area is situated on agricultural land that supports dry-land cropping and livestock. No agricultural land in the project area is mapped by the NSW Government to be biophysical strategic agricultural land (BSAL) and detailed soil analysis has established the absence of BSAL. This has been confirmed by the issue of a BSAL Certificate for the project area by the NSW Government.



LEGEND

- Project area
- Leewood
- Urban
- State forest
- Parks and reserves
- Aboriginal areas
- Lakes and dams
- Watercourses
- Highways
- Major Roads
- Train line
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor

0 5 10 20
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Narrabri Gas Project
EIS Technical Appendix

Regional context and location of key infrastructure

Job Number	21-22463
Revision	A
Date	12 Mar 2015

Figure 1

C:\Users\AFoddy\Desktop\21_22463_KBM29.mxd [KBM: 221]

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Data source: NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013. Created by: afoddy

2.3 Field Development and Constraint Planning Process

The Proponent uses a systematic framework for assessing site conditions and associated constraints and implementing a program of works that avoids, minimises and mitigates impacts. As part of the EIS process, The Proponent has characterised the terrestrial ecology within the project (and their sensitivity), aboriginal cultural heritage features, the location and distribution of other sensitive receptors and regulatory requirements for planning and project execution.

The Narrabri Gas Project Field Development Protocol (the Protocol) has been developed to ensure the phased development of the Narrabri Gas Project is undertaken in accordance with the impacts as assessed in the EIS and the approval conditions including the impact (or disturbance) limits for ecological communities and threatened species including impacts to Matters of National Environmental Significance (MNES) listed under the *Environmental Protection and Biodiversity (EPBC) Act 1999* and State requirements. This Protocol systematically identifies the constraints within the Narrabri Gas Project area considering sensitivity, conservation significance and legislative requirements and develops a framework for avoidance and minimisation of impacts.

The Protocol only covers activities associated with the planning and siting of gas field infrastructure. It is anticipated that a separate Plan of Operations (PoO) documenting the nature of construction and operational activities will be prepared which details the associated management and monitoring activities required. A PoO will be prepared for each phase of development and it is envisaged this will occur no less frequently than two yearly intervals (but may occur more frequently depending on the progress of development).

The key constraints identified in the Protocol for the Narrabri Gas project are summarised below. The constraints matrix in **Table 1** summarises which petroleum activities will be preferentially directed to specific areas. The following definitions have been applied for permitted activities identified in the constraints matrix:

- Support for planning – Monitoring including air quality, noise, ecological surveys and Aboriginal cultural surveys
- Non-linear infrastructure – Infrastructure including (but not limited to) exploration and production wells, small nodal compressor stations, water transfer tanks, small laydown areas and drilling camps (if needed).
- Linear infrastructure – Infrastructure including (but not limited to) gas and water gathering lines, low and high-pressure gas and water pipelines, roads and tracks, power lines and other service lines
- Large ponds and dams – Ponds and large dams greater than 100 ML capacity.

Table 1 Constraints matrix

Constraint category	Prohibited activities	Permitted activities	Ecological Sensitivity Class
No-go area	Petroleum activities are prohibited in this area.	NIL	Nature Reserves, National Parks, Aboriginal Areas
Surface development exclusion area	Linear infrastructure Non-linear infrastructure Large ponds and dams	Support for planning	State Conservation Areas
High constraint area	Large ponds and dams	Support for planning Linear infrastructure Non-Linear Infrastructure	High Moderate-High Note: ecological disturbance limits and siting of infrastructure process apply. Disturbance to high ecological sensitivity class limited to 0.5% of the total class area.
Moderate constraint area	Large ponds and dams	Support for planning Linear infrastructure Non-linear infrastructure	Low-moderate Moderate Note: ecological disturbance limits and ‘siting of infrastructure’ process apply
Low constraint area	No prohibited activities.	Support for planning Linear infrastructure Non-linear infrastructure Large ponds and dams	Low ecological sensitivity Note: ecological disturbance limits apply where relevant

Exclusion zones identified for the Narrabri Gas Project include but are not limited to the list in **Table 2**.

Table 2 Exclusion areas

Constraints / Exclusion Areas	Applicability
Nature Reserve / National Park / Aboriginal Areas	Exclusion from the project area
State Conservation Areas (Brigalow)	Exclusion of all surface infrastructure, and sub-surface exclusion to a depth of 110 m
Riparian Corridors	Exclusion of all non-linear surface infrastructure and large ponds and dams.
1% Annual Exceedance Probability (AEP) Flood Areas	Exclusion of all large ponds and dams
Currently known Aboriginal cultural heritage sites, Yarrie Lake	Exclusion of all surface infrastructure

Following exclusion from the areas described above, petroleum activities will be prioritised to lower sensitivity areas. To assess the range of potential outcomes based on the success of avoiding areas of higher ecological sensitivity calculations have been conducted separately for three separate scenarios with each potential development alternative. These comprise:

1. Base Case – Avoidance of only the attributes in **Table 2**
2. High Ecological Sensitivity Analysis (ESA) Avoidance – Avoidance of all exclusion areas (**Table 2**) and High Ecological Sensitivity Areas identified in the EIS.
3. High and Moderate-High ESA Avoidance – Avoidance of all exclusion areas (**Table 2**) and High and Moderate-High Ecological Sensitivity Areas identified in the EIS.

Further discussion of the disturbance calculations and avoidance of these ESAs is provided in **Section 3.0** and **5.0**.

2.4 Disturbance Estimation

The process of measuring 'actual' disturbances is well defined and includes baseline assessments and post-disturbance surveys to estimate actual disturbance. However, predicting a future disturbance (a disturbance that has not happened) is a more complicated process and requires an understanding of setting and the proposed development activity.

Similar to the process of calculating 'actual' disturbances, the estimation of disturbance for a defined development involves the use of defined project development plans and site data to define the potential disturbance. This process is used for the estimation of disturbance for major mining projects with intense assessment and engineering conducted to define the location of the development and the terrestrial ecology within the proposed development area.

However, this methodology is not practical for the estimation of potential disturbances associated with gas development projects. These projects are characterised by their dynamic nature with small infrastructure footprints dispersed over large areas (approximately 950 km^2). Further, the placement of wells and associated infrastructure is defined and evolves over the life of the project (based on the viability of the resource for development and other land use constraints). Therefore, provision of a defined disturbance within a specific footprint (as described above) prior to the commencement of project activities is not practical.

While the project and associated disturbances cannot be defined in these conventional terms, the nature and process of project development for gas projects is well defined. The magnitude of disturbance associated with specific infrastructure and the interrelationships between infrastructure types are defined. Further, in conjunction with exploration and appraisal activities (which will define areas of economic gas); the Protocol (as described above) will guide the development of the project in a manner that avoids key attributes and ensures the minimisation and management of impacts in areas where development does occur. Utilising this knowledge and the Protocol, a probabilistic methodology can be developed that provides 'representative' estimates of total project disturbance for a range of potential development scenarios.

2.4.1 Theory of Probabilistic Estimation of Disturbance

Probabilistic estimation is a well-developed science. Probabilistic methods consider a proposed action and its probability of causing or encountering a condition (e.g., probability of throwing a die and getting a six). The complexity associated with the probabilistic model is where multiple actions, causations or conditions are considered. Where this occurs, multi-variate analysis tools (Monte-Carlo Simulations) are conducted. Further discussion on this is provided in the sections below.

Despite this complexity, probabilistic estimation is a function of the proposed action and likelihood of causation or a condition. The key determinants of impacts for the project are the intensity of the proposed action (number of wells and associated linear infrastructure), the density of terrestrial ecological communities. Consistent with the probability analogy provided above, the magnitude of disturbance is a function of the intensity of disturbance (total area to be disturbed), the attributes of infrastructure (size and geometry) and the coverage of terrestrial ecological communities within an area undergoing development.

Using an understanding of the project constraints outlined in the Protocol, a probabilistic model was developed to provide a robust, clear and repeatable methodology for assessment of impacts to terrestrial ecology. This approach used standard probabilistic assumptions to determine the magnitude of disturbance and its dependency on total coverage of terrestrial ecological communities (the independent variable). Consistent with standard statistical methods, probabilistic ranges of disturbance have been calculated, and a defined probabilistic value of potential disturbance (90^{th} percentiles of a normally distributed population) have been applied to site data to determine a ‘predicted’ maximum site disturbance. The 90^{th} percentile has been utilised to provide a conservative estimate, which will not be exceeded on a cell-by-cell basis 90% of the time and effectively addresses inherent uncertainties in data and outcomes.

This methodology allows flexibility and calculates the probable disturbance distributions for a range of possible developments, based on differences in vegetation and habitat densities and infrastructure density, and has allowed The Proponent to assess multiple development scenarios (based on differences in the viability of gas resources in the area) in order to evaluate their maximum probable disturbance.

The following sections of the report discuss the probabilistic methodologies developed including:

1. The calculation of magnitude of disturbance based on coverage of sensitive terrestrial ecological communities;
2. The desktop, field-based and predictive modelling conducted to determine the extent of coverage of these communities; and
3. The integration of (1) and (2) above into an estimate of disturbance for specific ecological communities.

3.0 CALCULATION OF PROBABILITY AND MAGNITUDE OF DISTURBANCE

Monte-Carlo simulations were conducted to assess the effect of different densities of randomly generated vegetation and habitat maps compared to typical infrastructure footprints to provide probabilistic distributions of disturbance. The method involved multiple iterations of the model (3000 iterations) where the area of impacted vegetation/habitat for each realisation was recorded, and then various statistics were extracted from the simulated distribution to assess the potential impact. The analysis was completed independently for different levels vegetation/habitat in increments of 5% coverage, and for three different infrastructure footprints (1, 2 and 3 wells per km^2). This assessment was conducted separately for two different algorithms:

1. An algorithm (no avoidance) where the probability of encountering vegetation/habitat was estimated with no resampling based on only complete avoidance of exclusion areas.
2. An algorithm (with avoidance) where the probability of encountering vegetation/habitat was estimated with avoidance of exclusion areas and resampling if the infrastructure on the first sampling occasion (within the Monte-Carlo simulation) encountered vegetation communities and/or habitat.

The results of the 'avoidance' simulations were compared to the results from simulations with 'no avoidance' to assess the potential effectiveness of the Protocol and the avoidance and management strategies contained therein. As described below, this avoidance algorithm is considered to effectively represent the likely outcomes associated with the implementation of the Protocol and will provide considerable benefits over a development that did not utilise the Protocol (no avoidance algorithm).

There are numerous examples of applications of probabilistic methods in geo-spatial analysis. Although a literature search has not revealed specific applications to the infrastructure and vegetation/habitat disturbance analysis considered here, there are examples of applications in hazardous spill detection, wildlife mapping and general methodologies for sampling design. The basic algorithm applied here can be expressed analytically using the hyper-geometric probability distribution. The hyper-geometric distribution is a discrete probability distribution, and in this application, it describes the probability of impacting vegetation/habitat when trying to position a certain amount of infrastructure. However, when the basic problem is expanded to include avoidance strategies, the analytical approach does not fully represent the interactions, and Monte-Carlo methods are used to estimate the probabilities. Monte-Carlo methods are a broad class of computational algorithms that rely on repeated random sampling to obtain results and running simulations many times over in order to calculate the probabilities. They are often used in physical and mathematical problems and are most suited to be applied when it is impossible to obtain a closed-form expression or infeasible to apply a deterministic algorithm, such as the case when avoidance strategies are represented.

3.1 Methodology

The Narrabri Gas Project gas field comprises an area of 95,000 ha (950 km^2) over which develop could occur. To facilitate the integration of the probabilistic assessment with the GIS databases, the development area was divided into standard 1-km^2 blocks into which well and linear infrastructure (of differing densities) potentially could be placed. The 1-km^2 block provides a rational basis for a discrete representation of the potential variability in the distribution of habitat and ecological communities and is at sufficient scale to capture the range of well densities and associated linear infrastructure that may impact on this habitat. Further, the standard 1-km^2 block allows for the integration of the probabilistic assessments with the GIS data sets to provide the project estimates of disturbance.

For the purposes of the statistical assessment and in order to develop a system that can be used to assess the potential impacts of a multitude of development scenarios, each block was divided into four hundred 0.25-ha squares for the analysis to replicate the potential size of infrastructure that would be constructed in the field. The grid size was selected based on the size of petroleum infrastructure and to allow for assessment of the impact of percent vegetation coverage/habitat within each 0.25-ha cell and the aggregate disturbance within a theoretical 1km^2 development cell. This methodology is consistent with the use of Venn Diagrams (a probabilistic assessment tool), which is a standard methodology used to assess the probability of intersection (or conjunction) of two events, otherwise referred to as the union of two events (for example infrastructure intersecting vegetation or habitat).

3.1.1 General Methodology for Calculation of Theoretical Maximum Probable Disturbance

To assess the maximum probable disturbance associated with various development scenarios, the following algorithm was applied to the standard grid system described above. The implementation of the algorithm for maximum probable disturbance utilised the following methodology with the infrastructure considered fixed and the distribution of vegetation and habitat considered an independent variable:

1. Develop the infrastructure footprint by designating the fraction of each 0.25-ha block that potentially could contain infrastructure for a series of standard development scenarios (well densities and associated linear infrastructure).
2. Assess the impact of different densities of habitat on the probability of disturbance by randomly selecting the appropriate number of 0.25-ha squares (i.e., for 30% of total terrestrial ecology, select 120 out of the 400 squares) for each discrete 'percentage' of threatened ecological communities (TECs) or habitat.
3. For the squares with vegetation or habitats overlaid by infrastructure, sum the area of infrastructure footprints – this is the total vegetation/habitat impacted area.
4. Repeat steps 2 and 3, 3000 times and record the impacted area for each 'realisation'
5. Process the recorded values from the realisations to determine the 25th, 50th (median), 75th and 90th percentile values.

These computations produce a distribution of outcomes with the median and percentile statistics for the range of critical habitat coverage considered (i.e., 5% though 95% coverage in 5% increments for 19 coverages) developed for a range of infrastructure layouts. These layouts and disturbances capture the range of outcomes that could be encountered in discrete areas of the Narrabri Gas Project. These scenarios are summarised in **Table 3** below.

Table 3 Theoretical Development Scenarios

Scenario	Attributes
Scenario A – 1 well per km^2 of petroleum lease area	Development well pad of 1 ha
	Co-located access track/road and gathering lines – 10 m wide and 1 km long with associated tortuosity (total disturbance 1.0 ha)
Scenario B – 2 wells per km^2 of petroleum lease area	2 development well pads of 1 ha each (total disturbance of 2 ha).
	Co-located access track/road and gathering lines – 10 m wide and 0.8 km long with associated tortuosity for each well pad (total disturbance of 1.6 ha)
Scenario C – 3 wells per km^2 of petroleum lease area	3 development well pads of 1 ha each (total disturbance of 3 ha).
	Co-located access track/road and gathering lines – 10 m wide and 0.6 km long with associated tortuosity for each well pad (total disturbance of 1.8 ha)

The implementation of each of these layouts in the 400 square grid is shown in **Figure 2** through **Figure 4**

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.250	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 2 Infrastructure Layout for Scenario A (1 well) – 2 ha of aggregate disturbance (note each cell is 0.25 ha with the value provided in the cell an increment of 0.25 ha)

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.256	0.256	0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.256	0.256	0.256	0.00	0.00	0.00	0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.256	0.256	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.256	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.256	0.256	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.256	0.256	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3 Infrastructure Layout for Scenario B (2 wells)

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.267	0.267	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.267	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.267	0.267	0.267	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.267	0.267	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.267	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.267	0.267	0.267	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.267	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.267	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 4 Infrastructure Layout for Scenario C (3 wells)

To calculate the theoretical disturbance associated with different densities of vegetation, random sampling was completed for each of the 19 (5 to 95%) critical habitat coverages. This was conducted over 3,000 realisations within the Monte-Carlo simulations to derive probabilistic distributions of potential disturbance. An example of two of the random distributions generated for the 10 % coverage for Scenario A are shown in **Figure 5** and **Figure 6** below.

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.250	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 5 First Example Random Placeman of Critical Habitat for Scenario A

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.250	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 6 Second Example of Random Placeman of Critical Habitat for Scenario A

For the first example, the total critical habitat impacted is 0.5625 ha with 0.3125 contributed by access tracks (5 x 0.25 ha cells where 25% of the cell is disturbed) and 0.25 ha by the well pad (1 x 0.25 ha where 100% of the cell is disturbed). For the second example, the total critical habitat impacted is 0.6875 ha with 0.1875 contributed by access tracks (3 x 0.25 ha cells where 25% of the cell is disturbed) and 0.5 ha by the well pad (2 x 0.25 ha where 100% of the cell is disturbed). The random placement and impacted area calculation were repeated 3000 times for each of the 19 coverages in a Monte-Carlo type simulation.

The completion of the Monte-Carlo simulations for each of the 19 coverage levels yielded a discrete distribution of impacted areas with 3,000 values. An example of a typical distribution is illustrated in **Figure 7**.

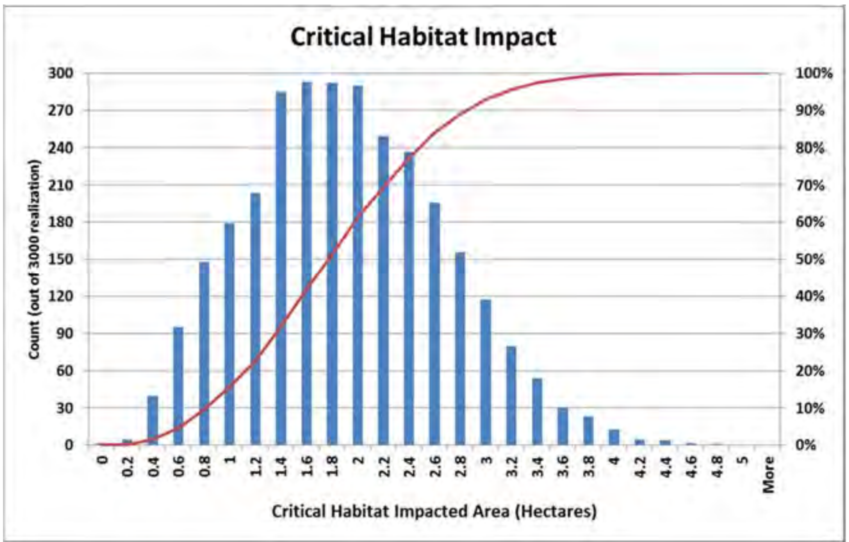


Figure 7 Histogram and Cumulative Distribution of Results for 45 % Vegetation and Habitat Coverage and Scenario C Infrastructure Layout

As pointed out previously, the basic algorithm can be represented by a close-formed solution using the hyper-geometric probability distribution. We can compare the results of Monte-Carlo simulations to those provided by the hyper-geometric distribution to validate the approach. The basic form of the distribution is

$$P(X=k)=\frac{\binom{K}{k}\binom{N-K}{n-k}}{\binom{N}{n}}$$

P(X=k) is the probability that the number of cells selected with critical habitat is equal to k, N is the total number of cells, K is the number of cells with critical habitat and n is the number of cells selected.

The term $\binom{a}{b}$ is the binomial coefficient and is defined as:

$$\frac{a!}{b!\,(a-b)!}$$

To validate the algorithm, we set up a 20-by-20-0.25 ha grid with 80 cells completely covered by infrastructure and assumed there is 50 ha randomly located with critical habitat. In this example, the total number of cells N = 400, the total number of cells with vegetation or habitat K = 200, and the number of infrastructure cells is n = 80 (i.e. the infrastructure). The Monte-Carlo simulation was executed for 3000 repetitions. The total number of realisations (i.e. 3000) was determined by using values of 750, 1500, and 3000. The difference in results obtained using 500 and 3000 repetitions was found to be insignificant and therefore 3000 repetitions was selected. The average number of critical habitat cells impacted was 10.1 ha and the variance was 3.9 ha^2. The average and variance associated with the hyper-geometric distribution are defined as:

$$Average = n\,\frac{\mathrm{K}}{N}$$

$$Variance = n\frac{K}{N}\frac{(N-K)}{N}\frac{(N-n)}{(N-1)}$$

Using the values specified above the average and variance are 10 ha and 4.04 ha^2. The good agreement indicates the Monte-Carlo simulation is providing accurate and reliable results.

Calculation of Disturbance

The calculation of the probable maximum disturbance without avoidance was based on the random placement of the critical habitat without regard to the presence of infrastructure and their potential impact on terrestrial ecology. Effectively after random placement in the models, no further attempt was made to relocate infrastructure to avoid disturbance of vegetation and habitat. This method, therefore, reflects a worst-case scenario and is not consistent with the Protocol and processes that will be implemented to minimise disturbance. However, the methodology does provide a means to compare the relative performance of the avoidance algorithm and associated total project disturbances.

In accordance with the Protocol described in **Section 2.3**, vegetation and habitat will be avoided if possible during development and execution of field development. This effectively will lead to infrastructure being preferentially placed in cleared areas or pasture.

To assess the potential success of avoiding vegetation or habitat, the basic process for random placement of critical habitat was modified to reflect the potential relocation of infrastructure. The relocation of infrastructure is not always practical because there are numerous constraints other than vegetation and habitat that affect the development. These include topography, other sensitive receptors, areas that cannot be lawfully disturbed, the location of resources and the need for minimum spacing between wells to maximise gas recovery. Therefore, this probabilistic estimate should only be considered an estimate of the probable minimum disturbance.

To replicate a scenario of conscious avoidance of vegetation/habitat, the methodology was modified to include a resampling of the cells in the event that a cell was encountered with vegetation or habitat. In effect, the modified algorithm randomly selected a second cell for placement when the initial selection yielded a cell with infrastructure. If the second cell also contained infrastructure, then the cell with the least amount of infrastructure was chosen for the placement of the critical habitat.

As anticipated (and described below), the results using the algorithm produced lower levels of vegetation/habitat impact, especially when the percent coverage was in the low to medium range. In accordance with the rationale contained within the Protocol, processes where development is biased towards already cleared areas (existing clearing and access tracks) will lead to lower project disturbances. A comparison of the disturbance estimates with and without avoidance is provided in **Table 4** below:

Table 4 Comparison of 90% Probability Total Disturbance Values for 1, 2 and 3 wells With and Without Avoidance (100% of cells in area available for development)

% Coverage	With Avoidance			Without Avoidance		
	1 well	2 well	3 well	1 well	2 well	3 well
	Total	Total	Total	Total	Total	Total
5	0.00	0.06	0.07	0.31	0.38	0.52
10	0.00	0.06	0.07	0.44	0.69	0.83
15	0.06	0.06	0.13	0.56	0.88	1.15
20	0.06	0.13	0.20	0.69	1.13	1.42
25	0.06	0.13	0.25	0.81	1.32	1.72
30	0.06	0.19	0.27	0.94	1.52	1.98
35	0.06	0.19	0.32	1.06	1.76	2.23
40	0.06	0.25	0.38	1.19	1.95	2.50
45	0.13	0.26	0.38	1.25	2.09	2.75
50	0.13	0.31	0.45	1.38	2.27	3.00
55	0.13	0.32	0.47	1.44	2.46	3.23
60	0.13	0.38	0.52	1.56	2.64	3.45
65	0.19	0.38	0.58	1.63	2.78	3.65
70	0.19	0.44	0.65	1.75	2.96	3.90
75	0.19	0.51	0.72	1.81	3.15	4.09
80	0.25	0.57	0.83	1.88	3.28	4.29
85	0.25	0.63	0.97	1.94	3.41	4.49
90	0.31	0.76	1.17	2.00	3.53	4.67
95	0.44	1.33	2.13	2.00	3.60	4.80
100	2.00	3.60	4.80	2.00	3.60	4.80

In accordance with the Protocol, different avoidance strategies exist for wells and linear infrastructure. Given that linear infrastructure must traverse the field and move gas, coal seam water and vehicles from one area to another, riparian zones and high and High Moderate Ecological Sensitive Areas cannot be excluded from potential development. Avoidance of all these areas is not practical (rivers and streams will have to be crossed) and if avoidance was implemented the increased length of tracks and pipelines (particularly in the forest) would result in greater project disturbances.

In accordance with the Protocol and where practical, well pads will avoid areas of higher ecological sensitivity. To assess the potential impact of this decision on disturbance limits for specific vegetation communities and habitat (both within and outside these areas), separate assessments were conducted for development scenarios where well pads were not placed in:

1. Riparian zones (base case)
2. Riparian Zones and High Ecologically Sensitive Areas
3. Riparian Zones and High/Moderate-High Ecologically Sensitive Areas

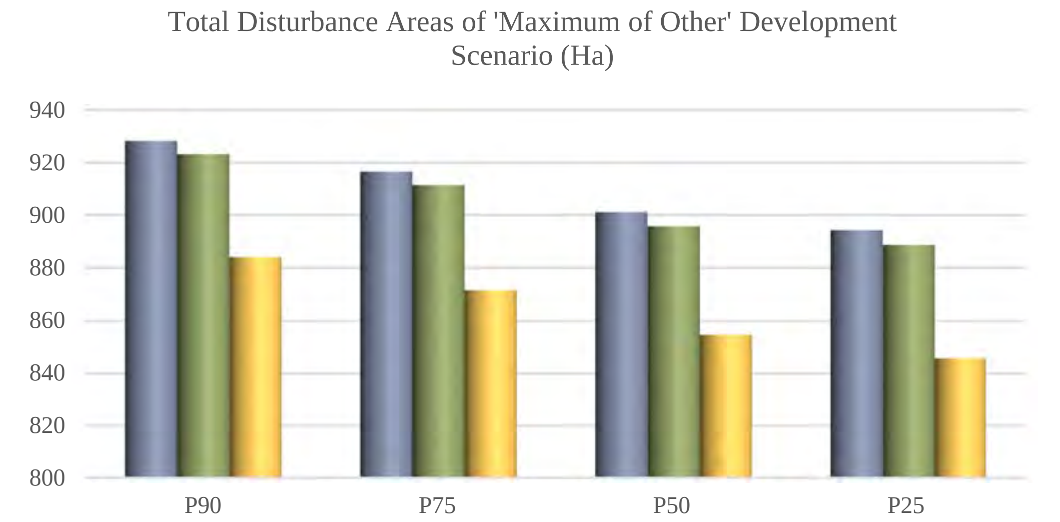
Table 5 Calculated disturbance values for Wells and Linear Infrastructure

P90 with avoidance (100% cell availability)									
% Coverage	1 well per cell			2 wells per cell			3 wells per cell		
	Total	Well	Linear	Total	Well	Linear	Total	Well	Linear
5	0.00	0	0	0.06	0.04	0.03	0.07	0.04	0.03
10	0.00	0.00	0.00	0.06	0.04	0.03	0.07	0.04	0.03
15	0.06	0.03	0.03	0.06	0.04	0.03	0.13	0.08	0.05
20	0.06	0.03	0.03	0.13	0.07	0.06	0.20	0.13	0.08
25	0.06	0.03	0.03	0.13	0.07	0.06	0.25	0.16	0.09
30	0.06	0.03	0.03	0.19	0.11	0.08	0.27	0.17	0.10
35	0.06	0.03	0.03	0.19	0.11	0.09	0.32	0.20	0.12
40	0.06	0.03	0.03	0.25	0.14	0.11	0.38	0.24	0.14
45	0.13	0.06	0.06	0.26	0.14	0.11	0.38	0.24	0.14
50	0.13	0.06	0.06	0.31	0.17	0.14	0.45	0.28	0.17
55	0.13	0.06	0.06	0.32	0.18	0.14	0.47	0.29	0.18
60	0.13	0.06	0.06	0.38	0.21	0.17	0.52	0.32	0.19
65	0.19	0.09	0.09	0.38	0.21	0.17	0.58	0.36	0.22
70	0.19	0.09	0.09	0.44	0.25	0.20	0.65	0.41	0.24
75	0.19	0.09	0.09	0.51	0.28	0.22	0.72	0.45	0.27
80	0.25	0.13	0.13	0.57	0.32	0.25	0.83	0.52	0.31
85	0.25	0.13	0.13	0.63	0.35	0.28	0.97	0.60	0.36
90	0.31	0.16	0.16	0.76	0.42	0.34	1.17	0.73	0.44
95	0.44	0.22	0.22	1.33	0.74	0.59	2.13	1.33	0.80
100	2.00	1.00	1.00	3.60	2.00	1.60	4.80	3.00	1.80

Other key decisions in the development of the model included determination of the appropriate probability threshold for the disturbance values used in the calculations and accounting for variability in the area available for development after consideration of exclusion areas.

Selection of Probability for Model Calculations

The Narrabri Gas Project has a number of unique aspects, most notably the differences in terrestrial vegetation density between the northern pastoral areas and the Narrabri State Forest. These differences in vegetation density and in particular vegetation densities greater than 80% (typically greater than 90% coverage) limit the ability and effectiveness of avoidance methodologies. As described above, the 90th percentile of the disturbance outcomes was selected for calculation of the project disturbance. This value has been selected rather than the median values for disturbance (P50 values), to provide confidence that other constraints will not limit the ability to avoid (especially where limited cleared areas exist) and result in actual disturbance greater than predicted disturbances. The relative impact on total project disturbances from the use of the P90 values relative to other percentiles is shown below in **Figure 8**. The use of the 90th percentile value (which will only be exceeded 10% of the time on a cell-by-cell basis) provides consistently higher estimates of total disturbance and is conservative given that the disturbance values are aggregated over multiple cells (900 cells).



	P90	P75	P50	P25
RIPARIAN	928.22	916.58	901.18	894.31
RIPIARIAN AND HIGH ESA	923.17	911.47	895.84	888.73
RIPARIAN AND HIGH AND MOD-HIGH ESA	884.11	871.52	854.77	845.82

Figure 8 Comparison of Total Disturbance Estimates for P90, P75, P50 and P20 Probabilistic Distributions

Area Available for Development

The presence of exclusion areas for all infrastructure and exclusion areas for wells only (depending on the scenario this can include riparian zones, high and moderate to high ESAs) leads to major reductions in the area available for development in each cell (less than 100 ha is available for potential development in each 1 km^2 cell). To account for a lower number of cells available for avoidance, separate algorithms (using the above principles) were developed for different available areas for development. Four different available areas of coverage for the 90th percentile using the avoid algorithm, are provided in **Table 6** below. As part of the calculation methodology, the available area for development of wells and linear infrastructure was determined and then the appropriate reference values selected for calculation. As shown in **Table 6**, a reduction in the area available for development directly impacts on the ability to avoid and therefore increases the potential disturbance associated with development (for example for the same vegetation cover high disturbance values are observed for grid squares where only 25% of the cells are available for development compared to 100%). Further details on the separate calculation methodologies are provided in the sections below.

Table 6 Availability of cell area for development and total disturbance by cell (ha) for 1, 2 and 3 well per cell development scenarios

P90 Avoidance Values												
% Vegetation Coverage	100% cell availability			75% cell availability			50% cell availability			25% cell availability		
	1 well	2 wells	3 wells	1 well	2 wells	3 wells	1 well	2 wells	3 wells	1 well	2 wells	3 wells
	Total Predicted Disturbance per cell in hectares											
5	0.00	0.06	0.07	0.00	0.00	0.00	0.00	0.06	0.07	0.06	0.13	0.13
10	0.00	0.06	0.07	0.00	0.00	0.00	0.06	0.13	0.20	0.06	0.19	0.32
15	0.06	0.06	0.13	0.00	0.00	0.07	0.06	0.13	0.25	0.13	0.26	0.38
20	0.06	0.13	0.20	0.00	0.06	0.07	0.06	0.19	0.32	0.13	0.32	0.52
25	0.06	0.13	0.25	0.00	0.06	0.07	0.13	0.25	0.38	0.19	0.44	0.58
30	0.06	0.19	0.27	0.00	0.06	0.13	0.13	0.31	0.45	0.19	0.50	0.72
35	0.06	0.19	0.32	0.00	0.06	0.13	0.13	0.32	0.52	0.25	0.57	0.83
40	0.06	0.25	0.38	0.06	0.13	0.20	0.13	0.38	0.58	0.25	0.63	0.90
45	0.13	0.26	0.38	0.06	0.13	0.20	0.19	0.44	0.65	0.31	0.70	1.03
50	0.13	0.31	0.45	0.06	0.19	0.27	0.19	0.50	0.70	0.38	0.77	1.17
55	0.13	0.32	0.47	0.06	0.19	0.32	0.25	0.57	0.78	0.38	0.89	1.30
60	0.13	0.38	0.52	0.06	0.19	0.33	0.25	0.57	0.85	0.44	0.95	1.43
65	0.19	0.38	0.58	0.06	0.26	0.40	0.31	0.64	0.97	0.50	1.08	1.62
70	0.19	0.44	0.65	0.06	0.32	0.47	0.31	0.75	1.10	0.50	1.20	1.80
75	0.19	0.51	0.72	0.13	0.32	0.58	0.38	0.82	1.23	0.56	1.33	2.00
80	0.25	0.57	0.83	0.13	0.44	0.67	0.44	0.95	1.42	0.63	1.52	2.32
85	0.25	0.63	0.97	0.19	0.51	0.85	0.44	1.08	1.63	0.75	1.84	2.70
90	0.31	0.76	1.17	0.19	0.70	1.17	0.56	1.39	2.18	1.00	2.21	3.22
95	0.44	1.33	2.13	0.38	1.52	2.34	1.00	2.21	3.22	1.31	2.91	3.92
100	2.00	3.60	4.80	2.00	3.60	4.80	2.00	3.60	4.80	2.00	3.60	4.80

4.0 DETERMINATION OF SPATIAL DISTRIBUTION OF TERRESTRIAL ECOLOGICAL AREAS

Following completion of the theoretical disturbance estimations described above, the assessment involved the integration of the probabilistic estimates of disturbance with project area specific terrestrial ecological data to develop site-specific estimates of potential disturbance. As described in the Technical Report on Terrestrial Ecology, detailed desktop and field-based assessments have been conducted to map the terrestrial ecology throughout the Narrabri Gas Project development area. Using predictive modelling techniques (based on the association of mapped data with ground-truthed data to determine vegetation and habitat types), individual vegetation community coverages and habitat have been assigned to the project area throughout the GIS domain.

Utilising the GIS database, 1 km^2-grid cells were assigned across the proposed development to align with the methodology used to provide probabilistic estimates of disturbance (refer **Figure 9**). Within each grid cell, values from the GIS system were assigned for the available area for development, the coverage of individual terrestrial ecological communities and the total coverage. The key data interrogated from the GIS and attributed to each grid cell is summarised in **Table 7** below, and the systematic grid with buffers around streams within the Narrabri Gas Project area shown on **Figure 9**.

The modelled data set provides the distribution and densities of vegetation and habitat against which the probabilistic disturbance criteria are then applied to calculate the project related disturbances. Maps of the distributions of the various vegetation classes outlined in **Table 7** are provided in **Appendix A**.

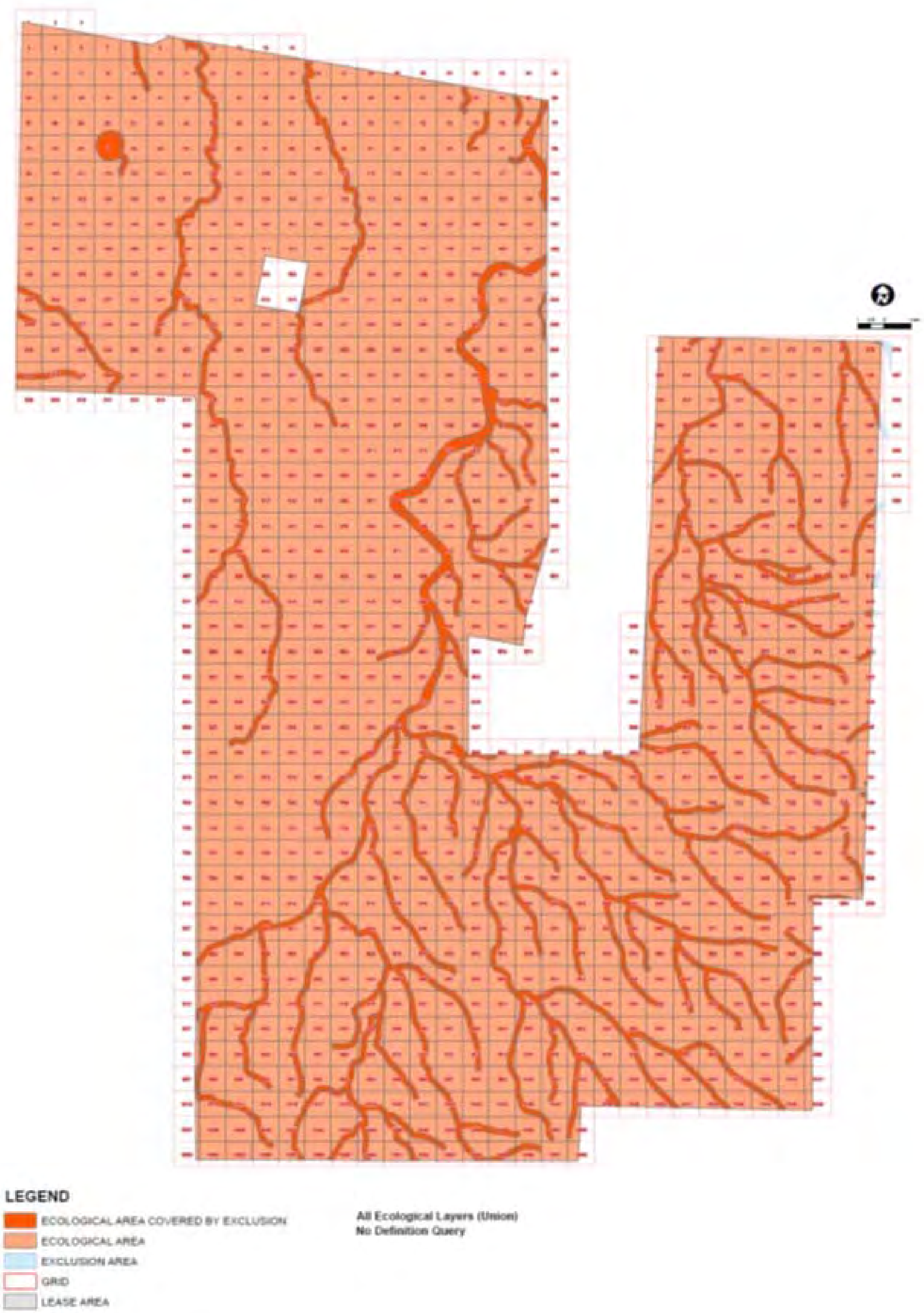


Figure 9 Constraint Categories and Grid Applied for the Constraints Planning Assessment Model

Table 7 Data Obtained from Each 1 km^2 Grid Cell within the GIS System

Key Data Queries by Grid Cell from GIS System
General Attributes
Unique Cell Identifier
Area of Cell within Lease
Area of cell within Exclusion
Areas of cell within Riparian Zone (no-go for wells)
Area of cell with High Ecological Sensitive Area
Area of cell with Moderate-High Ecological Sensitive Area
Area of cell available for development of Wells
Area of cell available for development of linear infrastructure
Total Vegetation and Habitat Coverage in cell area available for wells
Total Vegetation and Habitat Coverage in cell area available for linear infrastructure
Native Vegetation Types (not converted to grassland)
Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions [Native Vegetation]
Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion [Native Vegetation]
Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions [Native Vegetation]
River Red Gum riparian tall woodland/ open forest wetland in the Nandewar and Brigalow Belt South Bioregions [Native Vegetation]
Pilliga Box - White Cypress Pine – Buloke shrubby woodland in the Brigalow Belt South Bioregion [Native Vegetation]
Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion [Native Vegetation]
Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion [Native Vegetation]
Green Mallee tall mallee woodland rises in the Pilliga – Goonoo regions, southern BBS Bioregion [Native Vegetation]
Inland Scribbly Gum – White Bloodwood – Red Stringybark – Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP – Pilliga region in the BBS Bioregion [Native Vegetation]
Poplar Box – White Cypress Pine shrub grass tall woodland of the Pilliga – Warialda region, BBS Bioregion [Native Vegetation]
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 BBS Bioregion [Native Vegetation]
Red gum - Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion [Native Vegetation]
Rough barked Apple – red gum – cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region [Native Vegetation]
Mugga Ironbark – White Cypress Pine – gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion [Native Vegetation]
White Bloodwood – Red Ironbark – cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions [Native Vegetation]

Key Data Queries by Grid Cell from GIS System
White Bloodwood – Motherumbah – Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests [Native Vegetation]
Dirty Gum (Baradine Gum) – Black Cypress Pine – White Bloodwood shrubby woodland of the Pilliga forests and surrounding region [Native Vegetation]
White Cypress Pine – Silver-leaved Ironbark – Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion [Native Vegetation]
Spur-wing Wattle heath on sandstone substrates in the Goonoo – Pilliga forests, Brigalow Belt South Bioregion [Native Vegetation]
Carbeen – White Cypress Pine – Curracabah – White Box tall woodland on sand in the Narrabri – Warialda region of the Brigalow Belt South Bioregion [Native Vegetation]
White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests [Native Vegetation]
Vegetation Community 1 – PQDens>0
Vegetation Community 2 – BODens>0
Vegetation Community 3 – LMDens>0
Vegetation Community 4 – RPDens>0
Vegetation Community 5 – MIDens>0
Vegetation Community 6 – TLDens>0
Derived Native Grasslands from Former Native Vegetation Areas
Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions [DNG]
Brigalow – Belah open forest/ woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion [DNG]
Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions [DNG]
Pilliga Box – White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion [DNG]
Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion [DNG]
Poplar Box – White Cypress Pine shrub grass tall woodland of the Pilliga – Warialda region, BBS Bioregion [DNG]
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 BBS Bioregion [DNG]
Red gum – Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion [DNG]
Rough barked Apple – red gum – cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region [DNG]
Mugga Ironbark – White Cypress Pine – gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion [DNG]
Dirty Gum (Baradine Gum) – Black Cypress Pine – White Bloodwood shrubby woodland of the Pilliga forests and surrounding region [DNG]
White Cypress Pine – Silver-leaved Ironbark – Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion [DNG]
White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests [DNG]

Key Data Queries by Grid Cell from GIS System
Specific Habitat
Pilliga Mouse Habitat – Core
Pilliga Mouse Habitat – Support for Core

Note: DNG = Derived Native Grassland

5.0 IMPLEMENTATION OF THE PROBABILISTIC DETERMINATIONS TO GIS DATA SETS

Based on the probabilistic assessments and results described above, the magnitude of the total project disturbance can be calculated as a function of the distribution (and density) of ecological attributes and the intensity of development. The algorithms described above are applied to GIS data sets where the density of Terrestrial Ecological Communities and Habitat have been defined on a 1-km^2 grid (as described above) and shown in **Figure 9**.

The method involves the calculation of total potential project disturbance by the cell for three theoretical intensities of development (1, 2 or 3 wells per km^2). The estimated disturbances for each of development scenarios provide for estimates of total and individual terrestrial ecological communities by cell, which is then aggregated in total disturbance for each terrestrial ecological community. As the magnitude of disturbance is a function of total terrestrial ecology coverage and this relationship is not linear (rather increasing exponentially with the amount of coverage), the calculations must be conducted on a cell-by-cell basis and then aggregated.

The application of probabilistic criteria to the GIS database is conducted in a systematic manner, which involves defining the cells available for development and then assessing the magnitude of disturbance within the cells undergoing development. The general steps in the process are described below:

- **Step 1** – Define the cells and the area within cells in which development may occur for specific infrastructure. This involves excluding those grid squares or areas within grid squares where activities cannot lawfully or practically conducted (for example all exclusion areas and for wells the floodplain buffer around streams and creeks within the project area) or areas where no resource is anticipated and is not considered for development.

  In all development scenarios, the flood plain buffers around streams and creeks have been designated an exclusion area for well development. Linear infrastructure (access tracks and pipelines) are excluded from select areas in accordance with the Protocol but are able to transect exclusion zones that are solely prescribed for wells.

  In addition to the riparian zone exclusion areas (described above), a number of scenarios were conducted where high-value and moderate to high-value ecological areas were also identified as exclusion areas for wells. Details on the methodology for the definition of these high and moderate ecological areas is contained in the Terrestrial Ecology Technical Report. This modelling was conducted to assess the magnitude of disturbance on other vegetation areas and habitat from the exclusion of these areas and concentration of the development in remaining areas. Further discussion on the scenarios is provided below.

  An example of the assessment of areas available for development is provided as **Figure 9**, which shows the no-go (exclusion) zones established around the key stream and drainage features within the Project Area. Detailed maps showing the ecological areas are provided in **Appendix A**.

- **Step 2** – Define the area available within each 1 km square cell available for development and the total terrestrial ecological coverage within this available area. For example, each cell is 1 km^2 or 100 ha and after subtracting the no-go areas (Step 1 above) the remainder is defined (50 ha is 'no-go' then 50 ha of the cell is available for development). This value is defined separately for wells and linear infrastructure due to the different area.

- **Step 3** – Define the percent total coverage of terrestrial ecology within the available area (for example 10 ha of coverage exists within the 50 ha available area = 20% total coverage. This value is defined separately for well and linear infrastructure to facilitate calculation of disturbance values for each type of infrastructure.

- **Step 4** – Based on the percent of total coverage for terrestrial ecology (20%), calculate the magnitude of potential disturbance using the avoidance algorithm for the various theoretical development intensities (1, 2 or 3 wells per cell). The magnitude of disturbance is calculated separately for wells and infrastructure using the algorithm values provided in **Table 5** and **Table 6** above.
- **Step 5** – Assuming no hierarchical preference to disturbance of terrestrial ecology assign specific disturbances to individual terrestrial ecology grouping on the basis of the proportion that specific ecology makes up of the total vegetation and habitat coverage. Consistent with the other steps, these values are defined separately for wells and linear infrastructure.

  At this point in the assessment process, a disturbance value has been calculated for each individual terrestrial ecology group for three intensities of development (1, 2 and 3 wells per km2) in each individual grid square making up a tenement. This output from the model then forms the basis of the development scenario assessments described in Step 6 below.

- **Step 6** – Assess a specific development alternative by identifying the area in which the development could potentially occur (development focused in specific areas based on the potential viability of resources and/or geography) and then determining the number of cells within these areas available for development. Based on the projects defined number of wells relative to the number of cells available within the area for development, the following is completed:
  - Identify the intensity of development required to meet the project requirements (maximum development density of 1, 2 or 3 wells per cell). For example, if the number of wells slightly exceeds the number of cells then the disturbance values for 2 wells per cell will have to be utilised and the multiplied by a ratio as described below.
  - Identify and exclude cells with insufficient available area to support development (contiguous area available is less than the specified size for each development scenario)
  - Ratio the proposed number of wells by the available cells to average the theoretical disturbance calculations across the defined area and calculate a project specific disturbance by vegetation and habitat categories.
- **Step 7** – Repeat the process in Step 7 for a range of likely development scenarios (which reflect a range of different development intensities and development focus areas).
- **Step 8** – Aggregate the results for the development scenarios and conduct a qualitative assessment of the most probable development scenarios assigning values for the potential disturbance of each vegetation community and habitat to account for the range of future developments.

5.1 Modelled Development Scenarios

To facilitate an estimate of the maximum potential disturbance associated with the projects developments, a range of development scenarios were developed for the project reflecting differences in resource viability and geography. Scenarios assessed are provided in **Table 8** below and formed the basis of determining how decisions around areas of avoidance and focused development would affect the estimate of maximum disturbance. A number of the geographic development scenarios were utilised to assess the sensitivity of the model and validate the model outputs.

The development was based on 425 well pad disturbances and associated linear infrastructure. Development Scenarios A and D which extended over the entire project area were calculated based on 430 pad disturbances which comprised 425 wells and an additional 5 locations for core holes and/or appraisal wells (which are not converted to future development wells). Scenarios B2, B3, B4, C and E are developments focused on discrete areas of the project area (typically less than 40% of the total available area). These development scenarios were constrained to 375 well pad disturbances to reflect the maximum probable development intensity in these smaller areas.

Twenty-one separate scenario assessments were conducted with seven separate development scenarios (refer **Table 8**) with separate model outputs developed for each of the three no-go area assessments for wells (Stream Buffers only, Buffers/High Ecological Value Areas and Stream Buffers/High and Moderate-High Ecological Sensitive Areas). Further details on the mapping of ecological areas and definition of High and Moderate-High Ecological Value Areas is provided in the Terrestrial Ecology Technical Report and Protocol.

Table 8 Modelled Disturbance Scenarios

Scenario	Description	Well Exclusion Areas (no-go Areas)		
		Base Condition Riparian Zones only	Water Course and High Ecological Value Areas	Water Course and High and Moderate to High Ecological Value Areas
A	Wells evenly distributed over the entire area. The ratio of wells to available cells applied to the area.	X	X	X
B2	Southern-focused development in the Pilliga Forest	X	X	X
B3	Western focused development in the Pilliga Forest	X	X	X
B4	Northern-focused development on cleared farmland	X	X	X
C	Resource focused development based on water extraction areas - Areas 1 through 5 and 9	X	X	X
D	Resource focused development, wells distributed across all water extraction areas	X	X	X
E	Resource focused development in the area highest resource potential (currently)	X	X	X

The general findings for the development scenarios for the assessment of the various development scenarios are provided in **Table 9** below and a detailed assessment of the various scenario and the selection of the maximum probable disturbance is contained within the Terrestrial Ecology Technical Report. The table below includes values for each of the scenarios provided above as well as the maximum disturbance by vegetation type or habitat for each of the geographically biased developments (Scenarios A through C) considering the different exclusion area categories.

Consistent with the distribution of vegetation and habitat, the greatest potential disturbance of the majority of vegetation and habitat are associated with the developments focused in the Pilliga State Forest. For select communities (for example Brigalow) that are distributed preferentially in remnant areas of the vegetation of agricultural land, the maximum disturbances are associated with a northern focused development (Scenario B4).

Table 9 Example of Total Disturbances by Terrestrial Ecological Community for Various Development Scenarios (maximums from scenarios highlighted)

Scenario	A			B2			B3			B4			C2			MAX OF OTHERS (WITH AVOIDANCE)			SUM OF D			E		
Ecological Community Description	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH	ORIG	HIGH	H/MH
	430	430	430	375	375	375	375	375	375	375	375	375	375	375	375				430	430	430	375	375	375
	1042	1,040	1,010	388	388	375	385	385	377	422	421	419	321	320	298				1042	1040	1010	369	369	365
	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2				NA	NA	NA	1	1	2
	0.41	0.41	0.43	0.48	0.48	0.50	0.49	0.49	0.50	0.44	0.45	0.45	0.58	0.59	0.63				NA	NA	NA	1.02	1.02	0.51
Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions [Native Vegetation]	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.05	0.00	0.00	0.00	0.10	0.10	0.05	0.02	0.02	0.01	0.00	0.00	0.00
Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions [DNG]	0.19	0.19	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.50	0.00	0.00	0.00	0.48	0.48	0.50	0.09	0.09	0.09	0.00	0.00	0.00
Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion [DNG]	16.30	16.34	17.64	0.00	0.00	0.00	0.00	0.00	0.00	35.11	35.20	37.18	0.00	0.00	0.00	35.11	35.20	37.18	8.57	8.57	8.96	0.21	0.21	0.22
Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion [Native Vegetation]	8.48	8.49	7.20	0.00	0.00	0.00	0.00	0.00	0.00	18.74	18.78	15.66	0.00	0.00	0.00	18.74	18.78	15.66	4.11	4.11	3.39	0.08	0.08	0.08
Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions [DNG]	0.58	0.58	0.61	0.00	0.00	0.00	0.00	0.00	0.00	1.61	1.62	1.65	0.00	0.00	0.00	1.61	1.62	1.65	0.32	0.32	0.33	0.00	0.00	0.00
Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions [Native Vegetation]	1.37	1.38	1.77	0.00	0.00	0.00	0.00	0.00	0.00	3.04	3.05	3.82	0.00	0.00	0.00	3.04	3.05	3.82	0.66	0.66	0.82	0.00	0.00	0.00
River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions [Native Vegetation]	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.00	0.00	0.00	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion [DNG]	4.56	4.57	4.73	0.04	0.04	0.05	1.83	1.83	1.87	8.71	8.73	8.84	1.78	1.79	1.92	8.71	8.73	8.84	3.45	3.45	3.47	2.30	2.30	2.31
Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion [Native Vegetation]	23.36	23.43	23.84	3.40	3.39	3.61	34.10	34.14	34.43	19.01	19.08	19.18	27.90	28.04	30.16	34.10	34.14	34.43	29.27	29.31	29.06	34.26	34.29	33.69
Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion [Native Vegetation]	8.38	8.42	9.01	13.66	13.67	14.83	17.78	17.83	19.05	0.00	0.00	0.00	2.49	2.50	2.95	17.78	17.83	19.05	10.38	10.41	10.89	8.10	8.12	7.97
Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion [DNG]	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.02	0.02	0.03	0.02	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.00
Fuzzy Box Woodland on alluvial brown loam soils mainly in the NSW South-western Slopes Bioregion [Native Vegetation]	3.36	2.55	0.86	3.81	2.30	1.17	5.59	3.67	1.83	2.37	2.24	0.27	4.32	2.94	1.37	5.59	3.67	1.83	3.94	2.71	1.16	4.30	2.56	1.62
Green Mallee tall mallee woodland rises in the Pilliga - Goonoo regions, southern BBS Bioregion [Native Vegetation]	0.17	0.19	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.14	0.00	0.00	0.00	0.17	0.19	0.27	0.12	0.14	0.19	0.00	0.00	0.00
Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion [Native Vegetation]	0.90	0.90	0.93	1.92	1.92	2.03	1.94	1.94	2.02	0.00	0.00	0.00	2.32	2.33	2.55	2.32	2.33	2.55	2.26	2.26	2.53	2.21	2.21	2.09
Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion [DNG]	0.46	0.46	0.48	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	1.26	0.00	0.00	0.00	1.25	1.25	1.26	0.22	0.22	0.23	0.00	0.00	0.00

Scenario	A			B2			B3			B4			C2			MAX OF OTHERS (WITH AVOIDANCE)			SUM OF D			E		
Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion [Native Vegetation]	0.33	0.33	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.98	0.98	0.00	0.00	0.00	0.97	0.98	0.98	0.16	0.16	0.16	0.00	0.00	0.00
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 BBS Bioregion [DNG]	2.09	2.10	2.16	0.60	0.61	0.63	0.64	0.64	0.66	3.88	3.89	3.90	0.54	0.54	0.58	3.88	3.89	3.90	1.22	1.22	1.23	0.78	0.78	0.78
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 BBS Bioregion [Native Vegetation]	180.93	180.94	185.47	198.02	197.52	208.39	287.39	287.52	294.74	51.04	50.53	50.14	223.16	224.02	241.41	287.39	287.52	294.74	231.31	231.22	237.30	263.37	262.91	252.95
Red gum - Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion [DNG]	0.06	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.18	0.00	0.00	0.00	0.18	0.18	0.18	0.03	0.03	0.03	0.00	0.00	0.00
Red gum - Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion [Native Vegetation]	2.04	2.03	2.00	1.63	1.63	1.55	2.78	2.76	2.68	1.66	1.65	1.65	1.71	1.71	1.71	2.78	2.76	2.68	2.14	2.13	2.06	1.93	1.93	1.90
Rough barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region [DNG]	7.96	8.00	8.17	0.00	0.00	0.00	0.05	0.05	0.06	18.01	18.11	18.11	0.02	0.02	0.02	18.01	18.11	18.11	4.60	4.61	4.65	0.00	0.00	0.00
Rough barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region [Native Vegetation]	35.44	35.06	34.32	39.90	38.93	39.81	40.78	40.19	39.72	23.06	23.06	21.57	40.91	40.61	41.66	40.91	40.61	41.66	40.23	39.74	38.96	42.78	42.21	38.73
Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion [Native Vegetation]	0.71	0.71	0.73	0.00	0.00	0.00	0.00	0.00	0.00	1.62	1.62	1.63	0.00	0.00	0.00	1.62	1.62	1.63	0.40	0.40	0.41	0.00	0.00	0.00
Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion [DNG]	0.57	0.57	0.59	0.00	0.00	0.00	0.00	0.00	0.00	1.56	1.56	1.57	0.00	0.00	0.00	1.56	1.56	1.57	0.32	0.32	0.33	0.00	0.00	0.00
Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests [Native Vegetation]	84.29	80.98	70.37	69.11	68.57	71.91	21.65	21.70	25.64	37.67	36.38	36.10	100.04	93.27	64.19	100.04	93.27	71.91	78.77	76.20	69.37	34.60	33.73	30.15
White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions [Native Vegetation]	61.22	61.72	51.16	125.33	125.87	105.88	33.87	34.17	25.35	0.00	0.00	0.00	45.00	45.72	41.01	125.33	125.87	105.88	59.14	59.44	53.05	62.12	62.45	48.18
White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest mainly in east Pilliga forests [Native Vegetation]	34.00	34.90	37.85	61.30	62.01	67.25	2.56	2.57	2.82	2.15	2.03	1.99	20.41	22.75	28.15	61.30	62.01	67.25	40.32	41.31	45.32	10.27	10.61	10.60
Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region [DNG]	0.19	0.19	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	0.29	0.35	0.35	0.38	0.35	0.35	0.38	0.23	0.23	0.23	0.23	0.23	0.31
Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland of the Pilliga forests and surrounding region [Native Vegetation]	18.93	19.16	20.59	7.74	7.78	7.84	1.42	1.42	1.48	9.74	9.80	10.03	27.29	27.88	32.40	27.29	27.88	32.40	20.84	21.15	22.99	25.34	25.73	25.93
White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion [Native Vegetation]	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.21	0.00	0.00	0.00	0.21	0.21	0.21	0.03	0.03	0.03	0.00	0.00	0.00

Scenario	A			B2			B3			B4			C2			MAX OF OTHERS (WITH AVOIDANCE)			SUM OF D			E		
White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion [DNG]	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.28	0.00	0.00	0.00	0.28	0.28	0.28	0.04	0.04	0.04	0.00	0.00	0.00
Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion [Native Vegetation]	2.97	3.00	3.01	6.32	6.37	6.47	0.80	0.80	0.82	0.00	0.00	0.00	7.68	7.76	8.18	7.68	7.76	8.18	4.93	4.95	4.84	7.32	7.36	6.68
Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion [Native Vegetation]	0.04	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.07	0.00	0.00	0.00	0.08	0.08	0.07	0.02	0.02	0.02	0.00	0.00	0.00
White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests [DNG]	1.25	1.26	1.31	0.12	0.12	0.13	1.07	1.07	1.15	1.83	1.85	1.85	0.07	0.07	0.08	1.83	1.85	1.85	0.81	0.81	0.84	0.83	0.83	0.90
White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests [Native Vegetation]	54.23	54.90	48.03	81.09	82.22	66.71	117.47	118.96	103.12	7.76	7.83	7.80	81.74	82.91	68.34	117.47	118.96	103.12	76.69	77.45	64.98	89.03	90.18	74.00
Pilliga Mouse Habitat - Core	70.82	68.67	39.67	131.31	129.73	70.23	79.36	78.78	44.67	7.92	6.47	5.05	81.37	78.12	44.31	131.31	129.73	70.23	82.47	80.03	48.78	89.25	87.93	47.26
Pilliga Mouse Habitat - Support for Core	122.59	119.55	114.83	164.78	165.26	168.62	99.08	99.68	99.71	27.55	27.23	25.90	142.48	134.23	126.18	164.78	165.26	168.62	144.03	141.57	138.71	114.87	115.10	108.33
PQDens>0	0.70	0.44	0.24	0.28	0.18	0.15	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.81	0.41	1.44	0.81	0.41	0.65	0.41	0.26	0.00	0.00	0.00
BODens>0	4.94	3.09	2.69	0.00	0.00	0.00	0.00	0.00	0.00	3.80	1.58	1.06	6.37	5.19	4.98	6.37	5.19	4.98	4.04	2.64	2.73	0.00	0.00	0.00
LMDens>0	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.07	0.00	0.00	0.00	0.09	0.09	0.07	0.02	0.02	0.01	0.00	0.00	0.00
RPDens>0	0.06	0.04	0.04	0.14	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.07	0.07	0.08	0.04	0.04	0.00	0.00	0.00
MIDens>0	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.00	0.00	0.00	0.03	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
TLDens>0	1.39	1.39	0.92	3.18	3.18	2.18	3.21	3.20	2.17	0.00	0.00	0.00	3.85	3.85	2.75	3.85	3.85	2.75	3.05	3.04	1.99	3.41	3.41	2.24
	555.57	553.68	534.15	614.02	612.95	598.27	571.75	571.28	557.46	252.47	250.98	246.91	587.76	585.23	567.09	928.22	923.17	884.11	625.66	623.77	607.99	590.07	588.73	539.11

6.0 SUMMARY OF ASSESSMENT

Historical disturbance limits have been calculated using “calculation methods” where estimates of disturbances have been calculated as ‘absolutes’. The methods have utilised a systematic spacing (network) of wells and infrastructure that have been overlain onto maps of terrestrial ecology to provide estimates of disturbance. This method is fraught with limitations and has led to optimistic estimates of disturbance that have not effectively considered the other constraints or logistical considerations. As a result, these estimation methods have provided optimistic underestimates of the magnitude of disturbance, which do not reflect the dynamic and iterative nature of has development projects.

The development of gas resources utilises a systematic program of exploration, appraisal and development. This program of exploration and appraisal continues concurrently with development activities and determines the location, intensity and schedule of development. Reflecting this dynamic development framework, a probabilistic methodology was developed for calculating potential land disturbance, which considers that wells and linear infrastructure placement will evolve over time. The placement of infrastructure will be controlled and the methodology considers the exclusion areas and constraints that are documented in the Constraints Planning and Field Development Protocol. Further, the methodology assesses the potential benefits (where practical) of siting well pad outside of High and Moderate-High Ecologically Sensitive Areas.

The method utilised a series of steps including:

1. Development of probabilistic disturbance distributions for different densities of development.
2. Assessment and resolution of mapped and field data to develop a GIS database of terrestrial ecological communities over the development area.
3. Integration of the probabilistic disturbance distributions into the GIS database to develop estimates of disturbance for three different intensities of development.
4. Determination of the probable development scenarios and develop of project specific disturbance estimates.

The probabilistic method of calculating disturbance distributions used a series of Monte-Carlo simulations where the infrastructure (wells and linear infrastructure) were fixed in space, and the distribution and density of terrestrial ecology were the independent variable that was varied randomly. To replicate the decision-making process associated with avoidance, a resampling strategy was utilised in the statistical assessment to evaluate changes in the probability and magnitude of the disturbance. This resampling was constrained to reflect the limits on well pad placement (the well pads must be located proximal to the resource and at sufficient distance from other gas production wells).

Using the probabilistic disturbance distributions, project specific GIS data was integrated into the models to estimate the potential disturbance associated with three well scenarios for each of the project tenements. Using probable development scenarios maximum project disturbances with avoidance can be calculated by considering the ratio of proposed wells to available development cells within a proposed development area.

Assessment of a range of development scenarios, including development focused in specific areas of the field, allowed for assessment of potential variability in disturbance outcomes over the project life as well as the impact of avoidance decisions on vegetation communities located outside of the areas of avoidance.

This method provides a robust estimate for maximum disturbance as it considers both the inherent uncertainties associated with the phasing of oil and gas development work and the additional constraints and considerations for development of non-fixed infrastructure (e.g., gas field). The method is repeatable, transparent and suitable for assessment of the impacts of the project on Terrestrial Ecology.

7.0 REFERENCES

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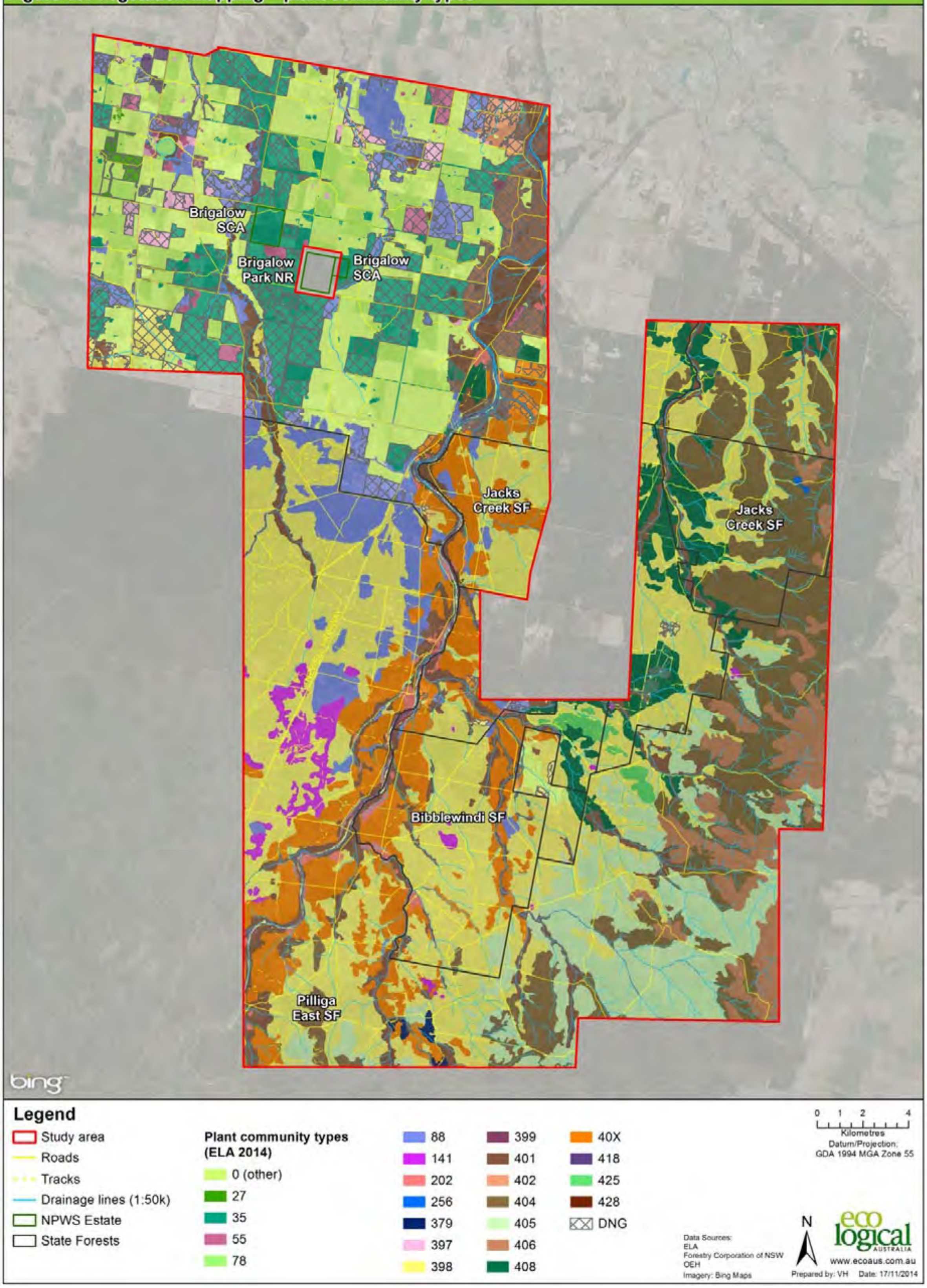
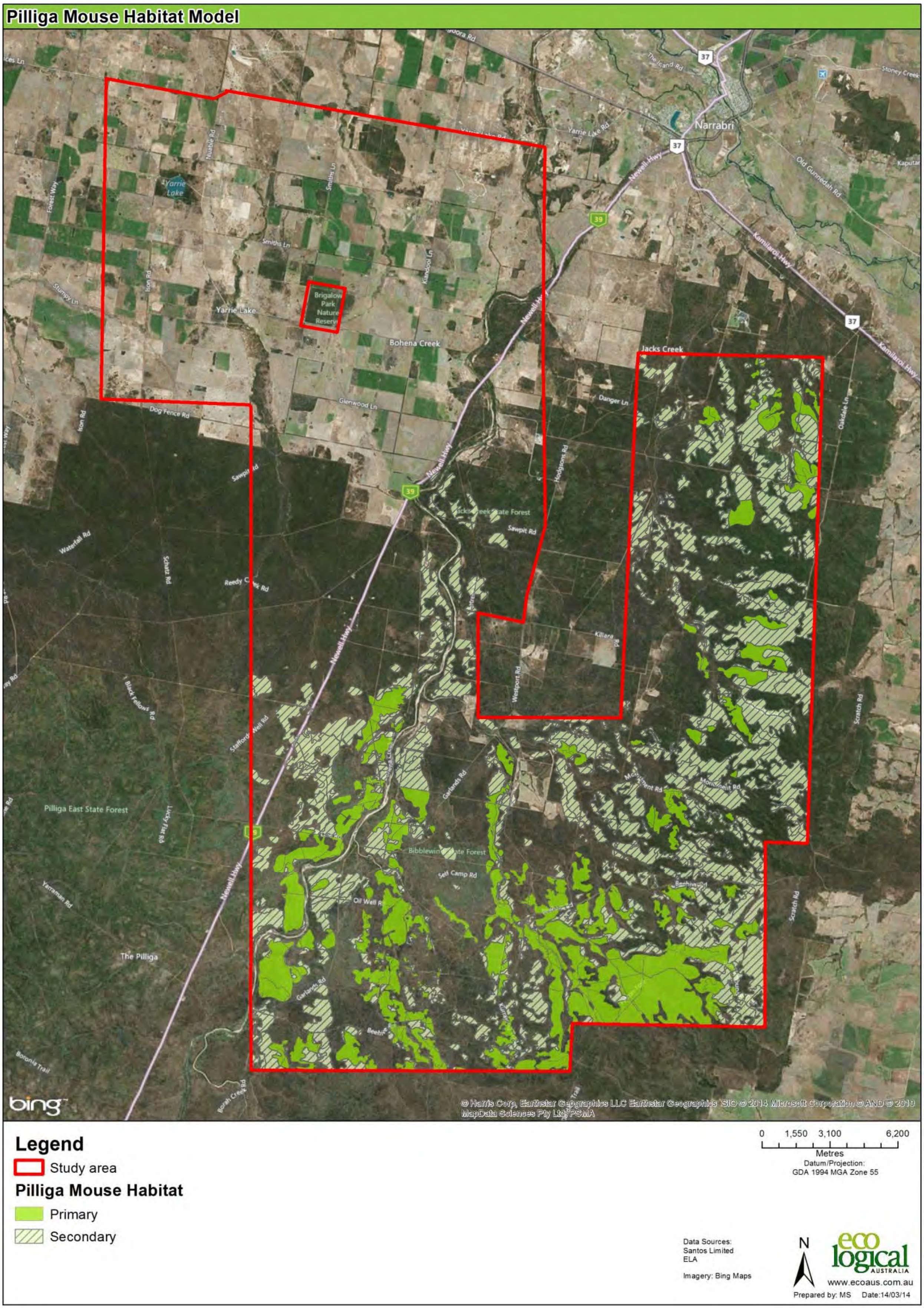
APPENDIX A MAPS OF TERRESTRIAL ECOLOGY WITHIN PROJECT AREA

Figure 15: Vegetation mapping – plant community types




Pilliga Mouse Habitat Model
Narrabri
Yarrie Lake
Brigalow Park Nature Reserve
Bohena Creek
Jacks Creek
Newell Hwy
Kamilaroi Hwy
Old Gunnedah Rd
Yarrie Lake Rd
Dog Fence Rd
Glenwood Ln
Danger Ln
Oakdale Ln
Hodgsons Rd
Sawpit Rd
Waterfall Rd
Schatz Rd
Reedy Creek Rd
Killara Rd
Westport Rd
Black Fellows Rd
Staffords Well Rd
Scratch Rd
Pilliga East State Forest
Lucky Flat Rd
Bibblewindi State Forest
Salt Camp Rd
Oil Well Rd
Garlands Rd
Yarraman Rd
The Pilliga
Bohena Trail
Borah Creek Rd
bing
© Harris Corp, Earthstar Geographics LLC Earthstar Geographics SIO © 2014 Microsoft Corporation © AND © 2010 MapData Sciences Pty Ltd, PSMA
Legend
Study area
Pilliga Mouse Habitat
Primary
Secondary
0 1,550 3,100 6,200
Metres
Datum/Projection:
GDA 1994 MGA Zone 55
Data Sources:
Santos Limited
ELA
Imagery: Bing Maps
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eco logical AUSTRALIA
www.ecoaus.com.au
Prepared by: MS Date:14/03/14

APPENDIX B LAND DISTURBANCE VALIDATION MEMO

Memorandum

Date: September 18, 2015
To: Joshua Gilroy, Santos Energy New South Wales
From: Dr. Mitchell Small and Nicholas Azzolina
Subject: Review of November 2014 Land Disturbance Probabilistic Calculation Methodology – Narrabri Gas Project

Distribution: Nigel Goulding David Nakles

The following memorandum provides an independent review and assessment of the maximum disturbance calculation methodology developed for the Energy NSW Narrabri Gas Project. This approach builds on a methodology already developed and implemented for estimation on Santos' other coal seam gas (CSG) development projects.

Minor modifications to the methodology developed for Queensland CSG projects have been conducted to better reflect the nature and size of proposed infrastructure for this proposed project. The methodology changes are only associated with development of the disturbance algorithms with a higher resolution 20×20 grid (400 cells) used in the modelling simulations. This higher resolution grid was selected to address the narrower width of infrastructure (namely access tracks and gathering pipelines) and manage potential step functions in the Monte Carlo simulations that could impact on the disturbance algorithm and ultimately the calculation of maximum project disturbance.

Two independent reviews were conducted. One review was conducted by Professor Mitchell J. Small, H. John Heinz Professor, Civil and Environmental Engineering & Engineering and Public Policy at Carnegie Mellon University. A second review was conducted by Dr. Nicholas A. Azzolina, Principal and Co-Founder of The CETER Group, Inc. Upon completion of these two independent reviews, Dr. Small and Dr. Azzolina collaborated on collating the comments and conclusions to develop this memorandum. Resumes for Dr. Small and Dr. Azzolina are provided in Attachment A of this memorandum.

OVERVIEW

Our review focused on the mathematical validity of the calculation methodology that was used in the Final Report. In addition, we reproduced the results for the 1-km^2 grid using a simple approximate method. This serves to further validate the core assumptions and simulation methods used in the Final Report and provides an alternative approach, complementary to the simulation method, for exploring development-disturbance relationships. The simulation approach should still be the primary tool applied in further studies, given its ability to consider non-idealized habitat and development patterns, such as avoidance, and the ability to integrate GIS data on land coverage.

In our opinion, the Final Report provides an overall effective and robust method for simulating the impact of alternative natural gas development patterns and density on land disturbance. The simulation approach and calculations are correct and the results have been properly interpreted. Moreover, the simulation approach is an effective method to accommodate the spatial constraints given the uncertainty in where the infrastructure will be placed until the exploration and appraisal are complete and the project has gone into detailed design.

We believe that possible extensions to the hypergeometric model can be used to provide approximate solutions for the vegetation or habitat impacted area as further validation for the Monte Carlo simulation approach. The approximation methods are described further below and demonstrate that the calculations as provided in the assessment are robust, repeatable and consistent with the predictive methodologies developed.

The remainder of this memorandum summarizes our review and discusses analytical extensions to the hypergeometric model, the avoidance algorithm, and integrating GIS data sets into the simulation approach.

ANALYTICAL EXTENSIONS TO THE HYPERGEOMETRIC MODEL

The hypergeometric distribution presented on page 14 of the Final Report properly describes the probability of encountering *k* cells with a specific vegetation or habitat in a random sample of *n* cells from a landscape with *N* total cells, of which *K* cells exhibit the specific vegetation or habitat ($k < n$, $n < N$, $k < K$). The ratio K/N represents the fraction of cells in the population exhibiting the specific vegetation or habitat, while k/n is the corresponding fraction in the sample. As indicated on page 14 of the Final Report, the mean and variance of *k* are given by:

$$\mathrm{E}[k] = n\,\frac{\mathrm{K}}{N}\,, \tag{1}$$

$$\mathrm{Var}[k] = n\frac{K}{N}\frac{(N-K)}{N}\frac{(N-n)}{(N-1)}\,, \tag{2}$$

For the 100-hectare (ha) (1-km^2) cell landscape (at 20×20 cells and 0.25 ha per cell) that is used as an example to validate the simulation results for the case where $N = 400$, $K = 200$, $n = 80$, and each cell is either fully covered with vegetation, with $x = 0.25$ ha (there are $K = 200$ of these) or without any vegetation, with $x = 0$ ha (there are N-K, or 200 of these). As such when the hypergeometric Equations 1 and 2 are applied to this case, they yield $\mathrm{E}[k] = 10$ and $\mathrm{Var}[k] = 4$. These results can be directly translated into the mean and variance of the total hectares encountered with vegetation or habitat, $\mathrm{E}[X] = 10$ ha and $\mathrm{Var}[X] = 4$ ha^2, where *X*, the total vegetation or habitat encountered (ha), is given by:

$$X = \sum_{i=1}^{n} x_i\,, \tag{3}$$

Equivalent results for the moments of k [dimensionless] and X [ha] are obtained because of the (0, 1) assumption for all x_i. While this does provide a useful (though first and partial) validation of the simulation, it is not applicable to the partial vegetation disturbance cases (within a cell) illustrated on pages 11 and 12 of the Final Report (Figures 2, 3 and 4). To more adequately address these, we suggest further approximate moment and distribution solutions for X. In so doing, it is recognized that the preferred approach will, in most cases, still be simulation, especially since the simulation approach is not subject to errors caused by deviations from the assumptions of the analytical approximations, such as correlation in the x_i of cells taken by infrastructure footprints (such as those shown in Figures 2, 3 and 4 of the Final Report).

A first approximation that may be considered is for the moments of X. While various approaches can be taken to this problem, the simplest is to consider the moment equations for the mean, E[X], and variance, Var[X], of the sum of n random variables:

$$\mathrm{E}[X] = \sum_{i=1}^{n} \mathrm{E}[x_i] \,, \tag{4}$$

$$\mathrm{Var}[X] = \sum_{i=1}^{n} \mathrm{Var}[x_i] \,, \tag{5}$$

The equation for the mean is exact in all cases while the equation for the variance only applies when the x_i are independent (or uncorrelated). Both positive correlation in the x_i (which increases Var[X]) and negative correlation (which decreases Var[X]) can occur (e.g., positive if infrastructure and habitat coverage are both clustered within an area; negative if high (low) coverage areas in the initial cells chosen make it more likely that low (high) coverage cells will be subsequently chosen). Recognizing that the variance equation is only approximate, it is worth comparing the approximate results that are obtained to that of the simulation method presented in the Final Report.

We explored both a normal distribution and a beta distribution as part of our review, and reproduced the simulation results for a 1-km^2 grid for Scenarios A, B and C for maximum disturbance without avoidance. Maximum disturbance without avoidance is based on random placement of the critical habitat without regard to the presence of infrastructure and their potential impact on terrestrial ecology. Effectively after random placement in the models, no further attempt is made to relocate infrastructure to avoid disturbance of vegetation and habitat.

Normal Distribution

The normal distribution approach involves the following sequence of steps. The Excel worksheet corresponding to these calculations is included as Attachment B to this review.

- **Step 1 –** Compute the mean and variance in land disturbance per 0.25-ha cell for Scenario A (1 well), B (two wells), and C (three wells), using the digital representations of each scenario from Figures 2, 3 and 4, respectively, of the Final Report.

- **Step 2 –** Multiply the mean and variance per cell by the percent of vegetation coverage for the entire 1-km^2 grid, which ranges from 5 to 95 percent in increments of 5 percent (i.e., 19 different vegetation coverage percentages). Calculate the standard deviation for each case by taking the square root of the variance.
- **Step 3 –** For each of the 19 vegetation coverages from 5 to 95 percent, calculate the median (P_{50}) for a normal distribution with a mean and standard deviation calculated in Step 2.
- **Step 4 –** Compare the results of this normal approximation to the simulation results for maximum disturbance without avoidance.

For example, in Scenario A there are 380 cells with no infrastructure development, 16 cells with 25% infrastructure development, and 4 cells with 100% infrastructure development, for an aggregate land disturbance of 4 ha [((0.25 × 16) + (1.00 × 4)) / 4 = 2 ha]. The mean and variance in land disturbance per hectare cell are 0.020 and 0.003, respectively. For the case with 25 percent vegetation (25 ha/100 ha), the mean and variance for the cell are multiplied by 25 to yield a mean of 0.5 ha and a standard deviation of 0.068 ha. The P_{50} of a normal distribution with these parameters is also 0.5 ha, which agrees well with the simulated value of 0.500 ha.

Graphical overlays of the simulated hectares impacted and the normal distribution estimates are shown below in Figure 1 for Scenarios A, B and C, as a function of the hectares of critical habitat included in the 1-km^2. These overlays show that a normal distribution provides a reasonable estimate for the land disturbance, and that the simulated hectares impacted and normal approximations agree. Data tables for each scenario and each of the different vegetation coverage percentages are included in the Excel file in Attachment B.

Beta Distribution

The beta distribution approach involves a similar sequence of steps as the normal distribution approach. However, the beta distribution is bounded within the region from 0 to 1, requiring the percentages of infrastructure development per cell to be divided by 100 prior to calculating the mean and variance. The two shape parameters of the beta distribution, *a* and *b*, are then calculated from the mean and variance using the following method of moments estimates:

$$a = \mu_x \left(\frac{\mu_x(1-\mu_x)}{\sigma^2} - 1\right), \qquad (6)$$

$$b = (1-\mu_x)\left(\frac{\mu_x(1-\mu_x)}{\sigma^2} - 1\right), \qquad (7)$$

Where:

μ_x = sample mean;
σ^2 = sample variance;

The Excel worksheet corresponding to these calculations is included as Attachment B to this review.

Graphical overlays of the simulated hectares impacted and the beta distribution estimates are shown below in Figure 1 for Scenarios A, B and C, as a function of the hectares of critical habitat included in the 1-km^2. These overlays show that a beta distribution also provides a reasonable estimate for the land disturbance, and that the simulated hectares impacted and the beta approximations agree. Data tables for each scenario and each of the different vegetation coverage percentages are included in the Excel file in Attachment B.

Conclusions from the Analytical Modeling

Both the normal distribution and beta distribution provide a reasonable estimate for the land disturbance and support the Monte Carlo simulation results for *maximum disturbance without avoidance*. The normal distribution provides a slightly better fit than the beta distribution to the simulated P_{50} land disturbance (lower root mean squared error [RMSE]). However, because the range for the normal distribution is from negative to positive infinity, the normal distribution will place a small probability mass below zero (i.e., negative land disturbance), which of course is nonsensical and undefined. If the goal is to use the normal distribution to estimate the P_{50}, then this effect is not significant as the P_{50} remains positive in all cases and closely matches the simulation results. However, if the goal is to use the normal distribution to both estimate the P_{50} and to quantify uncertainty, then the lower percentiles for cases with low percentages of habitat coverage (<10%) will be negative in some cases and therefore yield erroneous results. In contrast, the beta distribution is bounded between 0 and 1, thus it does not yield negative values. However, as noted above, the normal distribution provides a slightly better fit than the beta distribution to the simulated P_{50} land disturbance.

Each of the approximate analytical methods demonstrated above could serve a supporting, complementary role to the complete simulation method, especially if a large number of simulations for a large number of scenarios are needed. In addition, these analytical methods validate the results of the simulation approach at the unit scale (i.e., 1 km^2), which in turn supports the results of the implementation of the probabilistic method to GIS data sets for determining the maximum probable disturbance limits with avoidance.

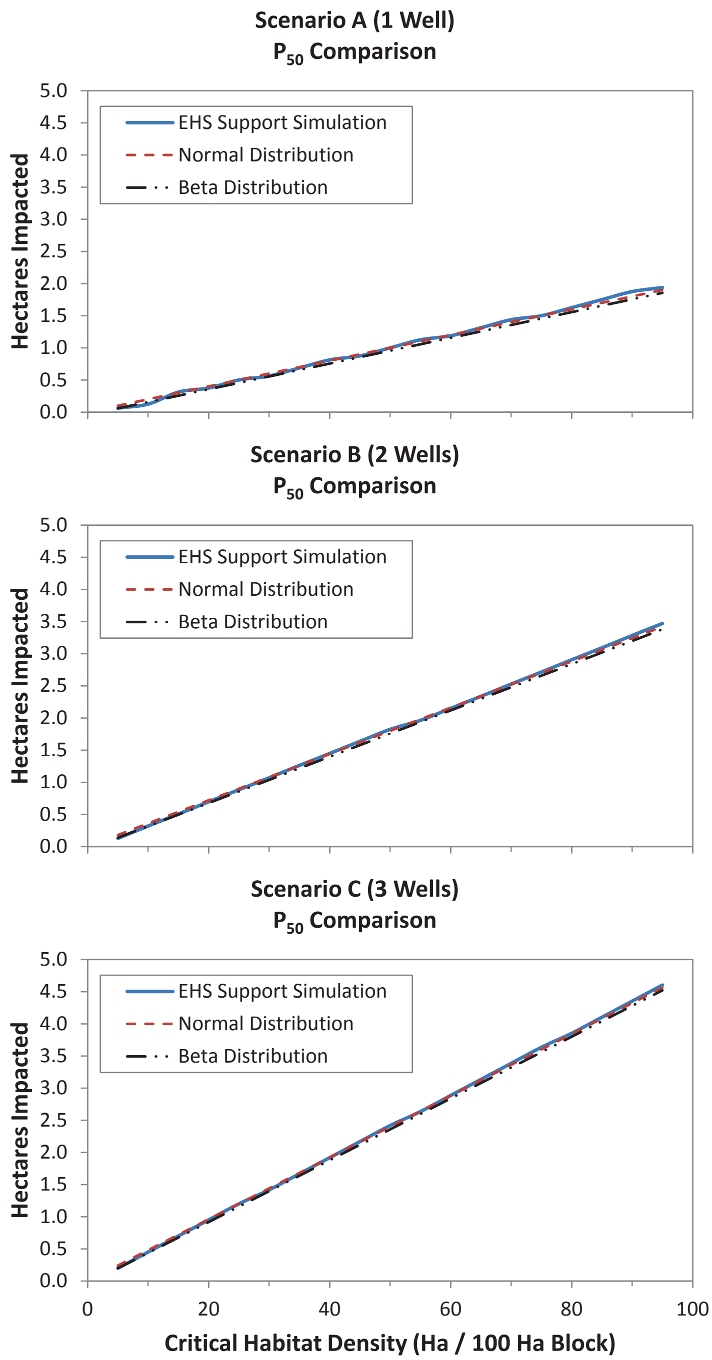

Figure 1. Graphical overlays of the P_{50} simulated hectares impacted for maximum disturbance without avoidance (solid blue line), normal distribution approximation (red dashed line), and beta distribution approximation (black dashed line) for Scenarios A (top), B (middle) and C (bottom), as a function of the hectares of critical habitat included in the 1-km^2 grid.

PROBABILISTIC APPROACH USING MONTE CARLO SIMULATION MODELING

EHS Support utilized the appropriate process of applying mathematical first-principles to develop a calculation methodology and calculations of disturbance which were robust and reproducible. The concept of using probabilistic methodologies to define the likely range of an outcome is well-defined in the literature and is the basis of many of research studies we commonly review. The use of Monte Carlo simulations has been appropriately leveraged to resolve multiple potential outcomes into an estimate of probable total disturbance and disturbance of individual vegetation communities. Notable references that support the application of these principles to the project objectives include Eckhardt (1987), Robert and Casella (2004), Ramaswami et al. (2005), and Rubinstein and Kroese (2007).

Avoidance Algorithm

The calculation of the probable maximum disturbance for a 1-km^2 grid without avoidance was based on random placement of the vegetation or habitat without regard to the presence of infrastructure and their potential impact on terrestrial ecology. This method does not reflect any potential relocation of infrastructure to facilitate a reduction in disturbance and may therefore be viewed as 'worst-case'. The analytical modeling described above shows that the Monte-Carlo simulation is providing accurate and reliable results for this system.

The random placement of vegetation/habitat was then modified to reflect the potential relocation of infrastructure with avoidance by resampling of the cells in the event that a cell was encountered with vegetation or habitat. The results shown in Table 6 of the Final Report indicate that the avoidance algorithm is correct and is producing logical results. For example, the avoidance algorithm produced lower levels of critical habitat impact, especially when the percent vegetation/habitat coverage was in the low to medium range. This is consistent with relocating infrastructure from the initial, random cell to an alternative cell with no or lower vegetation/habitat coverage. In addition, the nonlinear increase in critical habitat impact at higher percent vegetation/habitat coverage is consistent with having fewer alternative cells in these cases, thus making it less likely that resampling would identify an alternative cell. This effect appropriately increases for the two- and three-well development scenarios, which further supports the conclusion that the Monte Carlo simulation with avoidance is working correctly and is producing realistic results. A comparison between the 'without avoidance' and 'with avoidance' results for Scenarios A, B, and C, are shown in Figures 2, 3, and 4, respectively.

Area Available for Development

The 'without avoidance' and 'with avoidance' simulations represent two end-members, the former being most conservative and allowing no relocation of infrastructure, and the latter permitting relocation anywhere within the 1-km^2 block. However, the presence of exclusion areas for all infrastructure and exclusion areas for wells only leads to major reductions in the area available for development in each cell (i.e., less than 100 ha is available for potential development in each 1-km^2 cell). To account for a lower number of cells available for avoidance, separate algorithms were developed for different available areas for development: 25%, 50%, 75%, and 100% (where 100% would be equal to the full 'with avoidance' end-member). The relationships among these different cases are shown in Figures 2, 3, and 4. These figures further support that the Monte Carlo simulations with avoidance are working correctly and are producing realistic results. For example, the relationship is always 'without avoidance' > with avoidance 25% > with avoidance 50% > with avoidance 75% > with avoidance 100%. This result is exactly what would be expected – fewer cells available for development directly impacts on the ability to avoid and therefore increases the potential disturbance associated with development.

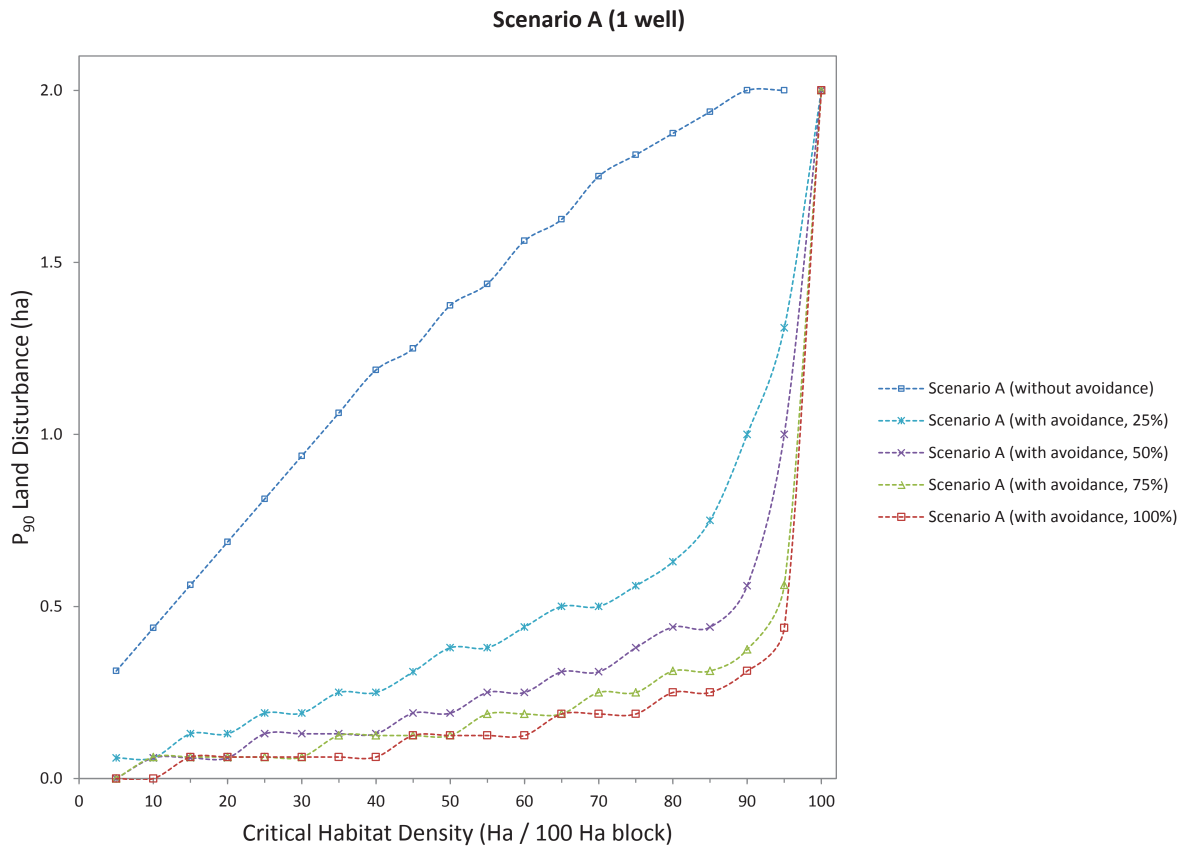

Figure 2. Comparison of Scenario A simulation results without avoidance (blue squares) and with avoidance for different percentages of area available for development: 25% (light blue asterisks), 50% (purple Xs), 75% (green triangles), and 100% (red squares).

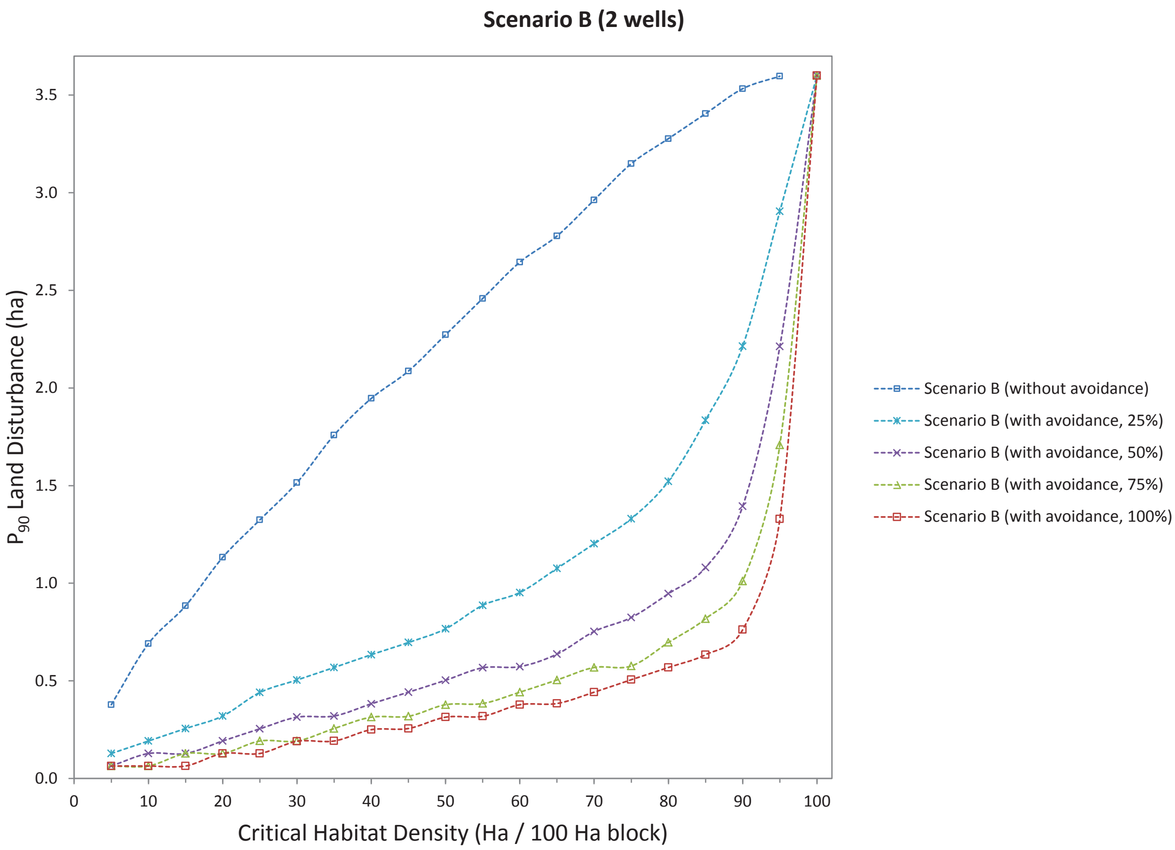

Figure 3. Comparison of Scenario B simulation results without avoidance (blue squares) and with avoidance for different percentages of area available for development: 25% (light blue asterisks), 50% (purple Xs), 75% (green triangles), and 100% (red squares).

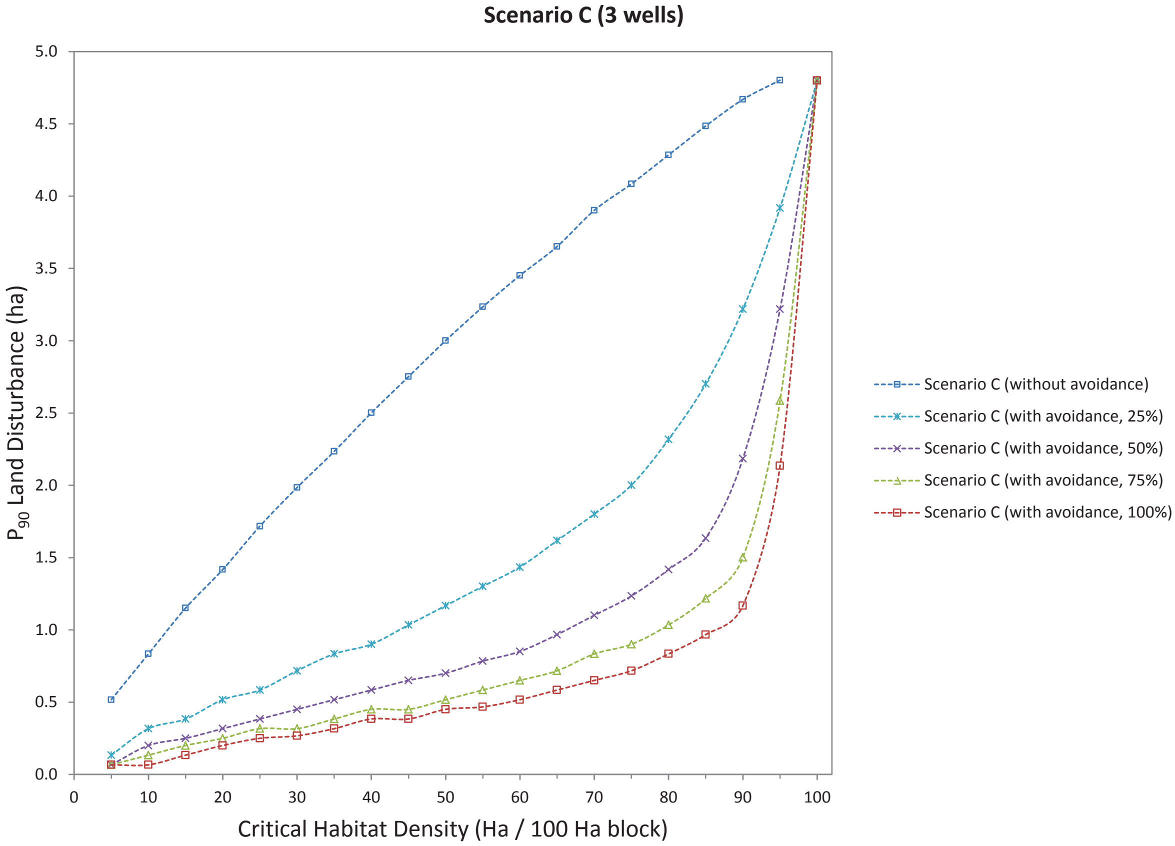

Figure 4. Comparison of Scenario C simulation results without avoidance (blue squares) and with avoidance for different percentages of area available for development: 25% (light blue asterisks), 50% (purple Xs), 75% (green triangles), and 100% (red squares).

Integrating GIS Data Sets into the Simulation Approach

The 1-km^2 grid cells were applied across the proposed development area and the Santos geographic information system (GIS) database was used to capture the project-specific spatial distribution of terrestrial ecological data. Additional information based on the current understanding of highest resource potential and infrastructure development was also incorporated into the GIS assessment. The probabilistic estimate of disturbance with avoidance was then applied to these 1-km^2 grid cells on a cell-by-cell basis and aggregated to yield an estimate for maximum disturbance across the entire proposed development area.

The sequences of steps described on page 24-26 of the Final Report define a logical, systematic approach for integrating GIS data into the Monte Carlo simulation approach. As was shown earlier, the cell-by-cell calculation approach is valid for determining the land disturbance within each cell using Monte Carlo simulation with the avoidance algorithm. The total amount of land disturbance would be additive, therefore it is valid to sum across each unique cell to estimate a total land disturbance. Thus the method used in the Final Report provides a representative estimate for maximum land disturbance within the proposed development area given the inputs of development intensity (1, 2 or 3 wells per km^2) and site-specific density of vegetation or habitat. In addition, the simulation approach is an effective method to accommodate the spatial constraints and to incorporate the decision rules of maximizing avoidance of higher ecological sensitivity and leveraging the use lower-sensitivity areas when available.

SUMMARY

As noted above, in our opinion, the Final Report provides an overall effective and robust method for simulating the impact of the iterative nature of coal seam gas development projects and their potential disturbance on vegetation and habitat assessment. In our review of the literature, no viable alternatives were identified. Additional calculation methodologies were identified which verify and validate the calculations developed in the Final Report.

Based on the assessment contained in this report, the simulation approach and calculations are correct and the results have been properly interpreted. Moreover, the simulation approach is an effective method to accommodate the spatial constraints given the uncertainty in where the infrastructure will be placed until the exploration and appraisal are complete and the project has gone into detailed design.

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- Assistant Professor, 1982-1987
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Professional and Honorary Society Memberships

American Geophysical Union
American Society of Civil Engineers
Association of Environmental Engineering & Science Professors
Chi Epsilon (Civil Engineering Honor Society)
International Society of Exposure Analysis
International Society for Industrial Ecology
Sigma Xi (Research Honorary Society)
Society for Risk Analysis

Recent Professional Activities

US EPA Science Advisory Board (SAB)
Member, Environmental Engineering Committee, 1985- 1991
Consultant to SAB, 1991-present
Chair of SAB Environmental Models Subcommittee, 1999-2003.
Recent SAB Panels:

- Member of SAB Expert Elicitation Advisory Panel, 2009.
- Member of SAB Dioxin Review Panel, 2010-2011

US EPA ORD Board of Scientific Counselors (BOSC), 1996 – 2002

US EPA External Review Panel for ORD National Exposure Research Laboratory, Ecological Research Division, 2007.

Member of National Research Council Committees:

- Hazardous Wastes in Highway Rights-of-Way, 1990-1993
- Remediation Priorities for Hazardous Waste Sites, 1991-1994
- USGS Water Resources Research, 1993-1996.
- Risk Characterization, 1994-1996.
- Environmental Remediation at Naval Facilities, 2000-2002.
- Changes in New Source Review Programs for Stationary Sources of Air Pollutants, 2004-2006.
- Review of Department of Homeland Security's Approach to Risk Analysis, 2008-2011.
- Risk Management and Governance Issues in Shale Gas Extraction, 2012 – 2014 (Chair).

Associate Editor, *Environmental Science & Technology*, 1995-2011.

Elected Councilor, Society for Risk Analysis (SRA), 1999-2002.
Planning Committee for First World Congress on Risk, Brussels, Belgium, June 2003.
Elected Secretary, 2005-2009.

Chair of DOE Independent Peer Review Committee for Multimedia Models for Use in Programmatic Environmental Impact Statement Risk Assessment, 1994.

Panelist for EPA Risk Assessment Forum review on Selecting Input Distributions for Exposure Assessment, 1997, 1998.

Review Panel Member for NIEHS Superfund Basic Research Program, 1999, 2012.

Scientific Advisory Committee, Harvard EPA Center on Ambient Particle Health Effects, 2000-2003.

EPA Peer Review Committee review of draft *Risk Assessment Guidance for Superfund (RAGS) Volume 3A*, 2000.

Member of EPA Science Advisory Board Review Panel for selection of EPA employees to receive Scientific and Technological Achievement Awards (STAA), 2001.

Member of Review Panel for EPA Superfund Minority Institutions Program on Hazardous Substance Research, 2002.

Member of Jury Panel for the Annual Heinz Award in Technology, the Economy and Employment, 2001 - 2003.

Member of External Peer Review Panel for Evaluation of US Army Corps of Engineers (COE) Risk-Informed Decision Framework for the Louisiana Coastal Protection and Restoration Project (LaCPR), 2006 - .

Independent Third Party Administrator for Peer Consultation Panel on EPA-DuPont PFOA Site Related Environmental Assessment Program, 2008-2009.

Appointed Expert Scientist to advise US EPA Ecological Research Program (ERP) on methods for Decision Support. Application to coral reefs management in US coastal waters, 2009 - .

Member of Allegheny County Health Department (ACHD) Air Toxics Advisory Committee reviewing revisions of the ACHD air toxics program, 2010 - .

Academic Advisory Panels:

University of North Carolina, Department of Environmental Science & Engineering, Graduate Program Review, April 2000.

Member of Review Panel for Helmholtz Gemeinschaft Research Programme in Earth and Environment: Sustainable Use of Landscapes, Leipzig-Halle, Federal Republic of Germany, June 2003.

Chair of Advisory Board for Cranfield University (UK) Research Council/Defra Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, 2009-2011.

Awards and Fellowships

Distinguished Educator Award, Society for Risk Analysis, December 2013

Best Reviewer Award, for journal *Risk Analysis*, December 2012.

Appointed as board-certified member of the American Academy of Environmental Engineers (AAEE) by eminence, December 2006.

Elected Fellow of the Society for Risk Analysis (SRA), December 2003.

2003 American Water Works Association (AWWA) Award for the Best Paper in the Small Systems Division, and the 2003 AWWA Publications Award (selected from the divisional winners), for the *Journal of the American Water Works Association* paper, "Point-of-use treatment and the revised arsenic MCL."

Frank Wilcoxon Prize, 1992, American Society for Quality Control – for best practical applications paper in the journal *Technometrics*, "Modeling lake-chemistry distributions: Bayesian methods for estimating a finite-mixture model."

National Science Foundation Presidential Young Investigator Award, 1986-1991.

The Universities Council on Water Resources, Inc., 1982 Award for the Outstanding Water Resources Thesis in the Field of Environmental and Water Resource Engineering.

Horner Award, 1980, American Society of Civil Engineers – for outstanding urban hydrology paper, "Stormwater interception and storage."

College of Engineering Fellowship, University of Michigan, 1978-1979.

Rackham Pre-Doctoral Fellowship, University of Michigan, 1980-1981.

Research Interests

Mathematical modeling of environmental quality; statistical methods and uncertainty analysis; human exposure modeling; human risk perception and decision making; integrated assessment models for human-environmental systems; ground water and soil pollution monitoring, site remediation, drinking water regulation and risk communication. Recent applications include design and analysis of leak detection monitoring systems at geologic CO_2 capture and storage sites, and decision support for protecting coral reefs.

PUBLICATIONS

Books

McDaniels, T.L. and M.J. Small (eds). 2004. *Risk Analysis and Society: An Interdisciplinary Characterization of the Field*. Cambridge University Press, Cambridge, UK.

Ramaswami, A., J.A. Milford and M.J. Small. 2005. *Integrated Environmental Modeling: Pollutant Transport, Fate and Risk in the Environment.* John Wiley & Sons, New York.

Journal Articles with Peer Review

Small, M.J. and W.P. Darby. 1976. Evaluating water quality impacts of small streams on major urban rivers. *J. Boston Society of Civil Eng., ASCE, 63*: 101-122.

Darby, W.P. and M.J. Small. 1976. Identifying urban flash flooding problems. *J. Wat. Res. Planning Mgt. Div., ASCE, 102*: 349-363.

Di Toro, D.M. and M.J. Small. 1977. Discussion of "Theory of storage and treatment plant overflows". *J. Env. Eng. Div., ASCE, 103*: 517-520.

Di Toro, D.M. and M.J. Small. 1979. Stormwater interception and storage. *J. Env. Eng. Div., ASCE, 105*: 43-54.

Small, M.J. and D.M. Di Toro. 1979. Stormwater treatment systems. *J. Env. Eng. Div., ASCE, 105*: 557-569.

Small, M.J. and P.J. Samson. 1983. Stochastic simulation of atmospheric trajectories. *J. Clim. & Appl. Meteor., 22*: 266-277.

Rhue, L.G. and M.J. Small. 1986. Application of a low-flow assessment model for the Monongahela River Basin. *Water Resources Bulletin,* 22: 121-127.

Small, M.J. and M.C. Sutton. 1986. A regional pH-alkalinity relationship. *Water Research*, 20: 335-343.

Small, M.J. and D.J. Morgan. 1986. The relationship between a continuous time renewal model and a discrete Markov chain model of precipitation occurrence. *Water Resources Research*, 22: 1422-1430.

Small, M.J. and M.C. Sutton. 1986. A direct distribution model for regional aquatic acidification. *Water Resources Research*, 22: 1749-1758.

Small, M.J. and J.R. Mular. 1987. Long-term pollutant degradation in the unsaturated zone with stochastic rainfall-infiltration. *Water Resources Research*, 23: 2246-2256.

Small, M.J., M.C. Sutton and M.W. Milke. 1988. Parametric distributions of regional lake chemistry: Fitted and derived. *Environmental Science and Technology*, 22: 196-204.

Small, M.J. and C.A. Peters. 1988. Public policy model for the indoor radon problem. *Mathematical Computer Modelling*, 10: 349-358.

Davidson, C.I., J.R. Harrington, M.J. Stephenson, M.J. Small, F.P. Boscoe and R.E. Gandley, 1989. Seasonal variations in sulfate, nitrate and chloride in the Greenland ice sheet: Relation to atmospheric concentrations. *Atmospheric Environment*, 23: 2483-2493.

Small, M.J. and P.J. Samson. 1989. Stochastic simulation of meteorological variability for long-range atmospheric transport: 1. Dynamic Lagrangian models. *Atmospheric Environment,* 23: 2813-2824.

Small, M.J., C. Bloyd, G. Keeler and R.J. Marnicio. 1989. Stochastic simulation of meteorological variability for long-range atmospheric transport: 2. Long-term statistical models. *Atmospheric Environment*, 23: 2825-2840.

Luthy, R.G. and M.J. Small. 1990. Environmental research: A clearer focus over a broader horizon. *Environmental Science & Technology*, 24(11): 1620-1623.

Sullivan, T.J., D.L. Kugler, M.J. Small, C.B. Johnson, D.H. Landers, B.J. Rosenbaum, W.S. Overton, W.A. Kretser, J. Gallagher. 1990. Variation in Adirondack, New York, lakewater chemistry a function of surface area. *Water Resources Bulletin*, 26: 167-176.

Rubin, E.S., M.J. Small, C.N. Bloyd and M. Henrion. 1992. An integrated assessment of acid deposition effects on lake acidification. J*ournal of Environmental Engineering, ASCE*, 118: 120-134.

Borrazzo, J.E., C.I. Davidson and M.J. Small. 1992. A stochastic model for diurnal variations of CO, NO, and NO_2 concentrations in occupied residences. *Atmospheric Environment* 26B: 369 -377.

Crawford, S.L., M.H. DeGroot, J.B. Kadane and M.J. Small. 1992. Modeling lake chemistry distributions: Bayesian methods for estimating a finite-mixture model. *Technometrics*, 34: 441-453.

Patwardhan, A. and M.J. Small. 1992. Bayesian methods for model uncertainty with application to future sea level rise. *Risk Analysis*, 12: 513-523.

Julien, B., S.J. Fenves and M.J. Small. 1992. Knowledge acquisition methods for environmental evaluation. *AI Applications*, 6: 1-20.

Julien, B., S.J. Fenves and M.J. Small, 1992. An environmental impact identification system. *Journal of Environmental Management,* 36: 167-184.

Wilkes, C.R., M.J. Small, J.B. Andelman, N.J. Giardino and J. Marshall. 1992. Inhalation exposure model for volatile chemicals from indoor uses of water. *Atmospheric Environment*, 26A: 2227-2236.

Giardino, N.J., E. Gumerman, N.A. Esmen, J.B. Andelman, C.R. Wilkes, C.I. Davidson and M.J. Small. 1992. Shower volatilization exposures in homes using tap water contaminated with trichloroethylene. *Journal of Exposure Analysis and Environmental Epidemiology*, Suppl. 1, 147-158.

Merz, J., M.J. Small and P. Fischbeck. 1992. Measuring decision sensitivity: A combined Monte Carlo-logistic regression approach. *Medical Decision Making*, 12: 189-196.

Ramaswami, A. and M.J. Small. 1994. Modeling the spatial variability of natural trace element concentrations in groundwater. *Water Resources Research*, 30: 269-282.

Dakins, M.E., J.E. Toll and M.J. Small. 1994. Risk-based environmental remediation: Decision framework and role of uncertainty. *Environmental Toxicology & Chemistry*, 13: 1907-1915.

Small, M.J., B.J. Cosby, R.J. Marnicio and M. Henrion. 1995. Joint application of an empirical and mechanistic model for regional lake acidification. *Environmental Monitoring & Assessment*, 35: 113-136.

Small, M.J., A.B. Nunn, III, B.L. Forslund and D.A. Daily. 1995. Source attribution of elevated residential soil lead near a battery recycling site. *Environmental Science & Technology*, 24(4): 883-895.

Siegel, E., H. Dowlatabadi and M.J. Small. 1995. Sensitivity and uncertainty analysis of an individual plant model and performance of its reduced form versions: A case study of TREGRO. *Journal of Biogeography*, 22: 689-694.

Siegel, E., H. Dowlatabadi and M.J. Small. 1995. A probabilistic model of ecosystem prevalence. *Journal of Biogeography*, 22: 875-879.

Brand, K.P. and M.J. Small. 1995. Updating uncertainty in an integrated risk assessment: Conceptual framework and methods. *Risk Analysis*, 15(6): 719-731.

Dakins, M.E., J.E. Toll, M.J. Small and K.P. Brand. 1996. Risk-based environmental remediation: Bayesian Monte Carlo analysis and the expected value of sample information. *Risk Analysis*, 16(1): 67-79.

Wolfson, L.J., J.B. Kadane and M.J. Small. 1996. Bayesian environmental policy decisions: Two case studies. *Ecological Applications,* 6(4): 1056-1066.

Wilkes, C.R., M.J. Small, C.I. Davidson and J.B. Andelman. 1996. Modeling the effects of water usage and co-behavior on inhalation exposures to contaminants volatilized from household water. *Journal of Exposure Analysis and Environmental Epidemiology,* 6(4): 393-412.

Kovacs, D.C., M.J. Small, C.I. Davidson and B. Fischhoff. 1997. Behavorial factors affecting exposure potential for household cleaning products. *Journal of Exposure Analysis and Environmental Epidemiology,* 7(4): 505-520.

Small, M.J. 1997. Groundwater detection monitoring using combined information from multiple constituents. *Water Resources Research,* 33(5): 957-969.

Small, M.J. 1997. Show me the data. *Journal of Industrial Ecology*, 1(4), 9-12. Invited column on Systems Modeling and the Environment.

Amekudzi, A., P. Fischbeck, J. Garrett, Jr., H. Koutsopoulos, S. McNeil and M. Small. 1998. Computer tools to facilitate brownfield development. *Public Works Management & Policy,* 2(3): 231-242.

Gross, L.J. and Small, M.J. 1998. River and floodplain process simulation for subsurface characterization. *Water Resources Research,* 34(9): 2365-2376.

Sinha, R., M.J. Small, P.F. Ryan, T.J. Sullivan and B.J. Cosby. 1998. Reduced-form modelling of surface water and soil chemistry for the tracking and analysis framework. *Water, Air and Soil Pollution,* 105: 617-642.

Stiber, N.A., M.J. Small and P.S. Fischbeck. 1998. The relationship between historic industrial site use and environmental contamination. *J. Air & Waste Management Association,* 48: 809-818.

Fischhoff, B., D. Riley, D.C. Kovacs and M. Small. 1998. What information belongs in a warning? *Psychology and Marketing,* 15(7): 663-686.

Diwekar, U. and M.J. Small. 1998. Industrial ecology and process optimization. *Journal of Industrial Ecology*, 2(3), 11-13. Invited column on Systems Modeling and the Environment.

Sohn, M.D. and M.J. Small. 1999. Parameter estimation of unknown air exchange rates and effective mixing volumes from tracer gas measurements for complex multi-zone indoor air models. *Building and Environment*, 34: 293-303.

Small, M.J. and P.S. Fischbeck. 1999. False precision in Bayesian updating with incomplete models. *Human and Ecological Risk Assessment,* 5(2): 291-304.

Stiber, N.A., M. Pantazidou and M.J. Small. 1999. Expert system methodology for evaluating reductive dechlorination at TCE sites. *Environmental Science & Technology*, 33(17): 3012-3020.

Farrow, R.S., C.B. Goldburg and M.J. Small. 2000. Economic valuation and the environment: A special issue. *Environmental Science & Technology*, 34(8): 1381-1383.

Fischhoff, B. and M.J. Small. 2000. Human behavior in industrial ecology modeling. *Journal of Industrial Ecology*, 3(2&3): 4-7. Invited column on Systems Modeling and the Environment.

Casman, E.A., B. Fischhoff, C. Palmgren, M.J. Small and F. Wu. 2000. An integrated risk model of a drinking-water-borne cryptosporidiosis outbreak. *Risk Analysis*, 20(4): 495-511.

Sohn, M.D., M.J. Small and M. Pantazidou. 2000. Reducing uncertainty in groundwater site characterization using Bayes Monte Carlo methods. *Journal of Environmental Engineering*, 126(10): 893-902.

Riley, D.M., M.J. Small and B. Fischhoff. 2000. Modeling methylene chloride exposure-reduction options for home paint-stripper users. *Journal of Exposure Analysis and Environmental Epidemiology*, 10 (3): 240-250.

West, J.J., M.J. Small and H. Dowlatabadi. 2001. Storms, investor decisions, and the economic impacts of sea level rise. *Climatic Change*, 48: 317-342.

Matthews, H.S. and M.J. Small. 2001. Extending the boundaries of life-cycle assessment through environmental economic input-output models. *Journal of Industrial Ecology*, 4(3): 7-10. Invited column on Systems Modeling and the Environment.

Riley, D.M., B. Fischhoff, M.J. Small and P. Fischbeck. 2001.Evaluating the effectiveness of risk-reduction strategies for consumer chemical products. *Risk Analysis*, 21, 357-369.

Casman, E., B. Fischhoff, M. Small, H. Dowlatabadi, J. Rose and M. G. Morgan. 2001. Climate change and cryptosporidiosis: A qualitative analysis. *Climatic Change*, 50: 219-249.

Kovacs, D.C., B. Fischhoff and M.J. Small. 2001. Perceptions of PCE use by dry cleaners and dry cleaning customers. *Journal of Risk Research,* 4(4): 353-375.

Gurian, P.L, M.J. Small, J.R. Lockwood III and M.J. Schervish. 2001. Benefit-cost estimation for alternative drinking water maximum contaminant levels. *Water Resources Research*, 37(9): 2213-2226.

Gurian, P.L, M.J. Small, J.R. Lockwood III and M.J. Schervish. 2001. Addressing uncertainty and conflicting cost estimates in revising the arsenic MCL. *Environmental Science & Technology*, 35(22): 4414-4420.

Lockwood, J.R., M.J. Schervish, P. Gurian and M.J. Small. 2001. Characterization of arsenic occurrence in source waters of US community water systems. *Journal of the American Statistical Association*, 96(456): 1184-1193.

Gurian, P.L. and M.J. Small. 2002. Point-of-use treatment and the revised arsenic MCL. *Journal American Water Works Association*, 94(3): 101-108.

Reichert, P., M. Schervish and M.J. Small. 2002. An efficient sampling technique for Bayesian inference with computationally demanding models. *Technometrics*, 44(4): 318-327.

Axtell, R.L., C.J. Andrews and M.J. Small. 2002. Agent-based modeling and industrial ecology. *Journal of Industrial Ecology*, 5(4): 10-13. Invited column on Systems Modeling and the Environment.

DeKay, M.L., M.J. Small, P.S. Fischbeck, R.S. Farrow, A. Cullen, J.B. Kadane, L. Lave, M.G. Morgan and K. Takemura. 2002. Risk-based decision analysis in support of precautionary policies. *Journal of Risk Research*, 5(4): 391-417.

Yeh, S. and M.J. Small. 2002. Incorporating exposure models in probabilistic assessment of the risks of premature mortality from particulate matter. *Journal of Exposure Analysis and Environmental Epidemiology*, 12(6): 389-403.

Mihelcic, J.R., J.C. Crittenden, M.J. Small, D.R. Shonnard, D.R. Hokanson, Q. Zhang, H. Chen, S.A. Sorby, V.U. James, J.W. Sutherland and J.L. Schnoor. 2003. Sustainability science and engineering: The emergence of a new metadiscipline. *Environmental Science & Technology*, *37*(23): 5314-5324.

Frey, H.C. and M.J. Small. 2003. Integrated environmental assessment, Part 1: Estimating emissions. *Journal of Industrial Ecology*, 7(1): 9-11.

Ailamaki, A., C Faloutsos, P.S. Fischbeck, M.J. Small, J. VanBriesen. 2003. An environmental sensor network to determine drinking water quality and security. *SIGMOD Record*, 32(4): 47-52.

Schultz, M.T., M.J. Small, R.S. Farrow and P.S. Fischbeck. 2004 State water pollution control policy insights from a reduced-form model. *Journal of Water Resources Planning and Management*, 130(2): 150-159.

Stiber, N.A., M. Pantazidou and M.J. Small. 2004. Embedding expert knowledge in a decision model: Evaluating natural attenuation at TCE sites. *Journal of Hazardous Materials*, 110(1-3): 151-160.

Gurian, P.L, M.J. Small, J.R. Lockwood and M.J. Schervish. 2004. Benefit-cost implications of multicontaminant drinking water standards. *Journal American Water Works Association*, 96(3): 70-83.

Lockwood, J.R., M.J. Schervish, P. Gurian and M.J. Small. 2004. Analysis of contaminant co-occurrence in community water systems. *Journal of the American Statistical Association*, 99(465): 45-56.

Boccelli, D.L., M.J. Small and U.M. Diwekar. 2004. Treatment plant design for particulate removal: Effects of flow rate and particle characteristics. *Journal of American Water Works Association*, 96(11): 77-90.

Karcher, S.C., M.J. Small and J.M. VanBriesen. 2004. Statistical method to evaluate the occurrence of PCB transformations in river sediments with application to Hudson River data. *Environmental Science & Technology*, 38(24): 6760 -6766.

Krayer von Krauss, M.P., E.A. Casman and M.J. Small. 2004. Elicitation of expert judgments of uncertainty in the risk assessment of herbicide tolerant oilseed crops. *Risk Analysis*, 24(6): 1515-1527.

Stiber, N.A., M.J. Small and M. Pantazidou. 2004. Site-specific updating and aggregation of Bayesian Belief Network models for multiple experts. *Risk Analysis*, 24(6): 1529-1538.

Ramaswami, A., J.B. Milford and M.J.Small. 2004. Integrated environmental assessment, Part II: Modeling fate and transport. *Journal of Industrial Ecology*, 8(3): 11-13.

Goyal, A., M.J. Small, K. von Stackelberg, D. Burmistrov and N. Jones. 2005. Estimation of fugitive lead emission rates from secondary lead facilities using hierarchical Bayesian models. *Environmental Science & Technology*, 39(13): 4929-4937.

Boccelli, D. L.; Small, M. J.; Dzombak, D. A. 2005. Enhanced coagulation for satisfying the arsenic maximum contaminant level under variable and uncertain conditions**.** *Environmental Science & Technology*, 39(17): 6501-6507.

MacDonald, J. and M.J. Small. 2005. Assessing sites contaminated with unexploded ordnance: Statistical modeling of ordnance spatial distribution. *Environmental Science & Technology*, 40(3): 931-938.

Weber, C.L., J.M. VanBriesen and M.J. Small. 2006. A stochastic regression approach to analyzing thermodynamic uncertainty in chemical speciation models. *Environmental Science & Technology*, 40(12): 3872-3878.

Boccelli, D., M.J. Small and D.A. Dzombak. 2006. Effects of water quality and model structure on arsenic removal simulation: An optimization study. *Environmental Engineering Science*, 23(5): 835-850.

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Bushey, J.T., M.J. Small, D.A. Dzombak and S.D. Ebbs. 2006. Parameter estimation of a plant uptake model for cyanide: Application to hydroponic data. *International Journal of Phytoremediation*. 8(1): 45-62.

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Gilau, A.M., R. Van Buskirk and M.J. Small. 2007. Enabling optimal energy options under the Clean Development Mechanism. *Energy Policy*, 35(11): 5526-5534.

Gilau, A.M. and M.J. Small. 2008. Designing cost-effective seawater reverse osmosis under optimal energy options. *Renewable Energy*. 33(4): 617-630.

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The CMU report provides information and decision tools designed to enable citizens and decision makers to better understand the linkage between climate change, land-use change, and specific resources that they are concerned about and manage. The resource domains where significant research and tool development were achieved include: water resources; ecological resources; energy use; human health; and coastal storm impacts. CMU contributions are included as part of the principal deliverable from the CARA project, the CARA web site: http://www.cara.psu.edu/ . See especially: http://www.cara.psu.edu/tools/tools.asp .

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Education

- Ph.D., Environmental Management and Science, Dept. of Civil and Environmental Engineering, Carnegie Mellon University, 2015
  - Dissertation: "Statistical Approaches to Quantifying Uncertainty of Monitoring and Performance at Geologic CO_2 Storage Sites"

- M.S., Hydrogeology and Aqueous Geochemistry, Dept. of Earth Sciences, Syracuse University, 2005
- A.B., Geological and Geophysical Sciences, Dept. of Geosciences, Princeton University, 1997

Select Project Experience

Sediment Assessments

- **Sediment Contaminant Bioavailability Alliance (SCBA), Nationwide:** Program manager for the SCBA, an industry consortium established to incorporate measurements of the bioavailability of sediment-bound PAHs into risk-based, environmental policies for defining cost-effective remedial action levels that are protective of human health and the environment. Managed work plans, sample collection, sample analysis, data analysis, and reporting for 20 case studies that were conducted throughout the U.S. and Canada at MGP, aluminum smelter, and other pyrogenic PAH sites. Organized meetings with U.S. EPA and various state agencies to review the case study results and advance the SCBA goals and objectives. These case study data have now been given to the Electric Power Research Institute (EPRI), where the data are available to Program 50 utility members.

- **Sediment Quality Triad (SQT) Studies, Multiple MGP Sites in New York State:** Managed all aspects of the work (planning, implementation and reporting) for multiple SQT studies in the Hudson and Mohawk Rivers, New York. Applied statistical techniques such as generalized additive modeling and nonparametric techniques such as non-metric multidimensional scaling to assess relationships among benthic macroinvertebrate community data and site-specific measurements of chemistry, toxicity, and physical parameters. Developed remedial action footprints using weight-of-evidence, risk-based approaches, which were significantly smaller in area and volume than those derived using sediment quality guidelines.

- **Statistical Data Analysis, Lower Passaic River, New Jersey (Confidential):** Currently supporting the detailed analysis of sediment and fish/crab tissue data associated with the remedial investigation of the Lower Passaic River Superfund project. The assessment includes summarizing PCB and dioxin/furan concentrations throughout the lower 17 miles of the river, evaluating the spatial distribution of contaminants (areal and vertical), examining source signatures (fingerprints) in the chemical data, linking sediment and fish/crab tissue concentrations, and identifying key assumptions that impact allocation.

- **Sediment Passive Sampling Study for PCBs, Portland, Oregon (Confidential):** Evaluating measurements of PCBs in sediment and sediment-exposed polyethylene (PE) from the Lower Willamette River. The data were collected to inform remedial cap design. The PE passive samplers were used to estimate pore water PCB concentrations, which may then be used to develop site-specific partitioning coefficients from sediment to pore water. Serving in a technical advisor role focused on data quality, analysis and interpretation.

- **Statistical Data Analysis, Portland, Oregon (Confidential):** Evaluated source attribution and ecological risk of sediments associated with the Portland Harbor Superfund Site. The scope of work entailed document review and statistical data analysis of the project database, which included more than $100 million of sampling and analytical work associated with samples collected within the project area. The analysis results will assist the client in addressing the draft remedial investigation and draft feasibility study reports currently proposed by U.S. EPA.

- **Statistical Data Analysis for Expert Testimony, North Carolina (Confidential):** Analyzed historical PCB congener data in lake sediment, lake water, and fish tissue to refute the claim that site-related PCBs were the source of fish tissue PCB concentrations. Integrated multiple statistical approaches such as Q Analysis, Analysis of Similarities (ANOSIM), and geostatistics to show using a weight-of-evidence approach that fish tissue more closely resembled background sources than site-specific PCB profiles.

- **Sediment Feasibility Study and Remedial Design, Ashland, Wisconsin:** Project manager for post-RI/FS data analysis of sediment NAPL and PAH concentrations at the Ashland/ NSPW Lakefront Superfund Site. Created and evaluated 3D models of contaminant distributions and assessed process calculations for sediment volumes, removal, dewatering, and disposal. Assessed FS cost estimates using Monte Carlo simulation. Represented Xcel Energy in meetings with U.S. EPA Region 5 and the Wisconsin DNR.

- **Long-term Monitoring of Water and Fish Tissue, Lower Fox River, Wisconsin:** Managed the planning, implementation, and reporting for the first year of a long-term, post-remediation monitoring program for Operable Unit 1 of the Lower Fox River. Evaluated multiple regression models to assess improvements in water and fish tissue PCB concentrations following dredging and capping. Represented GW Partners, LLC in meetings with U.S. EPA Region 5 and the Wisconsin DNR.

Oil and Gas Exploration and Production

- **Statistical Analysis of CO_2 Enhanced Oil Recovery (EOR) Industry Database:** Conducted statistical analyses of a proprietary industry data set of oil reservoir performance data from 31 different CO_2 EOR sites in Colorado, Oklahoma, Texas, and Utah. Developed novel two- and four-parameter nonlinear regression models for describing three key metrics that significantly influence the long-term performance and economic viability of CO_2 EOR projects: CO_2 retention, incremental oil recovery, and net CO_2 utilization. These results can be used by others to estimate the potential range of expected performance for similar candidate oil fields. In addition, these statistical models will be used by the U.S. Department of Energy (DOE) for estimating the carbon storage resource for CO_2 EOR projects throughout the United States.

- **Statistical Analysis of Bakken Oil Production Database Analysis, North Dakota:** Conducted statistical analyses of oil production data from 13 counties in North Dakota for wells producing from the Bakken formation, one of the largest oil plays in the United States. Developed and applied nonlinear regression model fits to more than 140,000 records from over 5,000 wells to assess correlations with potential predictors of oil production, including geology, reservoir conditions, and completion design. This work is ongoing and is aimed at optimizing oil production in the Bakken formation through the Bakken Production Optimization Program.

- **Monte Carlo Financial Risk Modeling for Oil-Based Drill Cuttings in North Dakota:** Developed a Monte Carlo-based simulation model to quantify the additional financial liability associated with burial of stabilized drill cuttings in on-site cuttings pits as well as off-site disposal of stabilized drill cuttings in special waste landfills. This liability is additional in the sense that it represents costs beyond the normal operating costs of the drilling operations. The modeling will be used by the Energy and Environmental Research Center (EERC) client (confidential) to help frame the market conditions and attendant opportunities that exist for managing oil-based drill cuttings in North Dakota.

- **Statistical Assessment of Groundwater Methane Concentrations in Northeastern Pennsylvania:** Analyzed a baseline dataset (confidential) of over 11,300 dissolved methane analyses from domestic water wells, densely arrayed in Bradford and nearby counties (Pennsylvania), and near to over 4,000 pre-existing oil and gas wells. Used an integrated approach of four different statistical methods to show that there is no statistically significant relationship between methane concentrations in domestic water wells and proximity to pre-existing oil or gas wells. The baseline data included more than 75% non-detect measurements with different laboratory minimum reporting limits; therefore, the statistical data analysis required unique solutions to appropriately handle correlation analysis and hypothesis testing with these data.

Geologic Carbon Sequestration

- **Risk Assessment for the Geologic Storage of Sour Gas (CO_2-H_2S) in a Saline Aquifer, British Columbia, Canada:** Provided support to the EERC in the development of a risk assessment for one of their Plains CO_2 Reduction (PCOR) Partnership Phase III carbon storage sites. The scope of work included [1] solicitation of expert opinion on the probability and severity of potential project risks; [2] integration of laboratory geochemical and geomechanical data on the reservoir and seal formations; [3] integration of reservoir petrophysical modeling results for sour gas extent and pressure buildup; [4] Monte Carlo statistical analysis of the project risks; and [5] development of the final report.

- **Risk Assessment for a CO_2 EOR Project in Southeastern Montana:** Provided support to the EERC in the development of a risk assessment for one of their PCOR Partnership Phase III carbon sequestration sites. The scope of work included [1] solicitation of expert opinion on the probability and severity of potential project risks; [2] preliminary Monte Carlo statistical analysis of the project risks; and [3] development of an internal memorandum. The project is on-going, and a follow-up risk assessment will be conducted in the future.

- **Programmatic Risk Assessment for the PCOR Regional Carbon Sequestration Partnership:** Provided support to the EERC in the development of a risk assessment of the PCOR Partnership program, which is required for all seven of the Regional Carbon Sequestration Partnerships (RCSPs) by the U.S. DOE. This effort was completed using the same approach and protocols that had been developed for the demonstration test sites. This project is on-going, as U.S. DOE requires periodic updates of this risk assessment throughout the duration of the program.

Mining Hydrogeology

- **Mining Permit Hydrogeologic Baseline Characterization, Michigan (Confidential):** Managed the bedrock hydrogeology assessment for a non-ferrous mine permit application in Michigan. Scope of work included hundreds of bedrock cores, optical borehole imaging, hydrophysical logging, inflatable packer testing, constant-rate pump tests, and 3D geostatistical modeling. Represented the client in meetings with the Michigan DEQ.

- **Mining Operational Water Balance Model, Manitoba, Canada (Confidential):** Supported the mining operational water balance model associated with the development of a nickel mine in Manitoba, Canada. The water balance model included a detailed, time-series model of frac sand tailings, ultramafic waste rock, mill tailings, nickel tailings, and waste rock, along with climate data (temperature, precipitation, etc.), hydrology (surface and groundwater), and other operational inputs.

EPRI Projects

- **EPRI Sediment Research White Paper:** Compiled over 20 years of EPRI sediment-related research into a white paper for a prospective Program 50 utility member. While the EPRI sediment-related research has covered a wide array of topics, most of the documents could be classified according to three topic areas, which were the focus of the white paper: [1] sediment PAH bioavailability and toxicity; [2] monitored natural recovery; and [3] sediment capping.

- **EPRI Groundwater Research White Paper:** Compiled over 20 years of EPRI groundwater-related research into a white paper for a prospective Program 50 utility member. While the EPRI groundwater-related research has covered a wide array of topics, most of the documents could be classified according to five topic areas, which were the focus of the white paper: [1] source characterization and leaching; [2] groundwater contaminant transport modeling; [3] monitored natural attenuation; [4] in-situ groundwater treatment; and [5] ex-situ groundwater treatment.

- **ASTM Method Report:** Managed the inter-laboratory validation study for an innovative analytical method for measuring trace organic chemicals in sediment pore water for the purpose of developing a new ASTM analytical method. The project involved a statistical analysis of seven independent data sets that were generated by four analytical laboratories who applied the new analytical method to blind samples of impacted sediment pore waters. A final report was generated and submitted to ASTM. Based on this report, the method was successfully balloted and approved, yielding a new ASTM Standard Method, D7363-13: "Standard Test Method for Determination of Parent and Alkyl Polycyclic Aromatics in Sediment Pore Water Using Solid-Phase Microextraction and Gas Chromatography/Mass Spectrometry in Selected Ion Monitoring Mode".

- **DNAPL Mobility White Paper:** Developed a technical white paper entitled, "Technical Protocols for Assessing DNAPL (Dense Non-Aqueous Phase Liquid) Mobility in the Subsurface at MGP Sites", which was developed to assist EPRI members in securing environmental closure of sites that had been impacted by MGP site DNAPL residuals. It summarizes EPRI research that has been conducted on DNAPL mobility at MGP sites and presents technical protocols for conducting DNAPL mobility assessments at MGP sites using currently available methods and/or technologies. The technical protocols address each of the primary zones of the subsurface environment: [1] vadose zone; [2] saturated zone; and [3] bedrock (both competent and fractured). The report also presents a DNAPL mobility database, which was assembled from the available EPRI research.

- **Sediment Assessment Protocol:** Developed a technical brief for a sediment assessment protocol entitled, "Incorporating Direct Measurements of Bioavailability into Sediment PAH Assessments at MGP Sites", which discusses the incorporation of analytical method ASTM D7363-13 (SPME pore water method) into ecological risk assessments and subsequently into the establishment of regulatory clean-up goals for environmental closure of MGP sites with impacted sediments.

- **Transfer of the Sediment PAH Bioavailability Database to EPRI:** This project formally transferred the SCBA database to EPRI, and involved the development of an on-line database and query format so that EPRI Program 50 utility members may access and utilize the database. The current EPRI Database contains data for 618 sediment samples collected from a total of 20 different sites (3 aluminum smelters, 14 MGPs, 1 U.S. Navy yard, 1 steel mill, and 1 urban background location). A subset of these samples (330 sediment samples from 3 aluminum smelter, 10 MGP, and 1 U.S. Navy yard site) was characterized in detail for PAH bioavailability.

Other Project Experience

- **Statistical Analysis of MGP Soil Vapor Intrusion (SVI) Database for New York State:** Working on behalf of the New York utilities and the Environmental Energy Alliance of New York (EEANY), and collaborating with the New York State Department of Environmental Conservation (NYSDEC) and Department of Health (NYSDOH). Analyzed the database of SVI data from site investigations conducted at 83 MGP sites in New York State, which includes more than 3500 air samples. Developed and applied new nonparametric statistical techniques to account for non-detect measurements, unequal numbers of vapor samples across sites, and variable laboratory method reporting limits. Currently developing a manuscript in collaboration with NYSDEC and NYSDOH to summarize the work and complement the current SVI guidance for MGP.

- **Soil Background PAH and Metals Study, Manhattan, New York:** Project Manager for the evaluation of background soil concentrations of PAH and metals in Manhattan. The project was designed to complement the statewide survey conducted jointly by the NYSDEC and NYSDOH. Managed the planning, implementation, and reporting for collecting samples from 27 locations throughout Manhattan. Developed summary statistics and percentile estimates for 46 PAHs and 23 metals, along with descriptions of surface and subsurface soils and measurements of total organic and black carbon.

Software Skills

- Microsoft Word, Excel, PowerPoint, and Access
- Visual MODFLOW and Ground Water Vistas (ground-water modeling)
- ESRI ArcMap, SEGA GIS, Visual Sample Plan (geospatial mapping)
- PHREEQC and VisualMINTEQ (geochemical reaction modeling)
- Minitab, Netica, PAST, R, and SAS (statistical modeling)

Employment History

- Independent Consultant/The CETER Group, Inc. [August 2010 to Present]
- Scientist/Project Manager, Foth, Green Bay, Wisconsin [2008 to 2010]
- Scientist/Project Manager, The RETEC Group, Inc., Ithaca, New York [2005 to 2008]
- Scientist, O'Brien and Gere Engineers, Inc., Syracuse, New York [2004 to 2005]
- Research Assistant/Head Teaching Assistant, Syracuse University, Department of Earth Science, Syracuse, New York [2003 to 2005]
- Supervisor, McMaster-Carr Supply Co., Dayton, New Jersey [2000 to 2003]
- Senior Field Engineer, Schlumberger Oilfield Services, Edinburg, Texas [1997 to 2000]

Peer-Reviewed Publications

- Anders, K.M.; **Azzolina, N.A.**; Doroski, M.A.; Distler, M.A.; Heitzman, G.W.; Neuhauser, E.F.; Singh, A.; and Rabideau, A.J. 2015. Concentrations of MGP-related compounds measured during soil vapor intrusion investigations at manufactured gas plant sites in New York State. Manuscript in preparation.

- **Azzolina, N.A.**; Kreitinger, J.P.; Skorobogatov, Y.; Shaw, R.K.; Mascuch, L.; and Ripp, J.A. 2015. Background Concentrations of PAHs and Metals in Surface and Subsurface Soils Collected throughout Manhattan, New York. *Environmental Forensics*, In-press.

- **Azzolina, N.A.**; Nakles, D.V.; Gorecki, C.D.; Peck, W.D.; Ayash, S.C.; Melzer, L.S.; and Chatterjee, S. 2015. CO_2 storage associated with CO_2 enhanced oil recovery: A statistical analysis of historical operations. *International Journal of Greenhouse Gas Control*, 37:384-397.

- Siegel, D.I.; **Azzolina, N.A.**; Smith, B.J.; Perry, A.E.; and Bothun, R.L. 2015. Methane concentrations in water wells unrelated to proximity to existing oil and gas wells in northeastern Pennsylvania. *Environmental Science and Technology*, 49(7):4106-4112.

- **Azzolina, N.A.**; Neuhauser, E.F.; and Coulombe, B.D. 2015. A statistical evaluation of sediment quality triad benthic community measurements in PAH-impacted sediments at a manufactured gas plant site along the Hudson River. *Soil and Sediment Contamination: An International Journal*, 24(7):744-770.

- **Azzolina, N.A.**; Small, M.J.; Nakles, D.V.; Glazewski, K.A.; Peck, W.D.; Gorecki, C.; Bromhal, G.S.; and Dilmore, R.M. 2015. Quantifying the benefit of wellbore leakage potential estimates for prioritizing long-term MVA well sampling at a CO_2 storage site. *Environmental Science and Technology*, 49(2):1215–1224.

- **Azzolina, N.A.**; Neuhauser, E.F.; Finn, J.T.; Crawford, T.R.; Anders, K.A.; Doroski, M.A.; Perretta, A.C.; Distler; M.A.; Heitzman, G.W. 2014. Volatile Organic Compounds from Coal Tar and Soil Vapor Samples at MGP Sites, *Environmental Forensics*, 15(3):225-233.

- **Azzolina, N.A.**; Small, M.J.; Nakles, D.V., Bromhal, G.S. 2014. Effectiveness of subsurface pressure monitoring for brine leakage detection in an uncertain CO_2 sequestration system, *Stochastic Environmental Research and Risk Assessment*, 28:895-909.

- Singh, A.; Neuhauser, E.F.; **Azzolina, N.A.**; Distler, M.A.; Anders, K.A.; Doroski, M.A.; and Rabideau, A.J. 2013. Statistical techniques for analyzing of soil vapor intrusion data: A case study of manufactured gas plant sites. *Journal of the Air & Waste Management Association*, 63(2):219-229.

- Hawthorne, S.B., Jonker, M.T.O., van der Heijden, S.A., Grabanski,C.B., **Azzolina, N.A.**, and Miller, D.J. 2011. Measuring picogram per liter concentrations of freely dissolved parent and alkyl PAHs (PAH-34), using passive sampling with polyoxymethylene. *Analytical Chemistry*, 83(17):6754-6761.

- Arp, H.P., **Azzolina, N.A.**, Cornelissen, G., and Hawthorne, S.B. 2011. Predicting pore water EPA-34 PAH concentrations and toxicity in pyrogenic-impacted sediments using pyrene content. *Environmental Science and Technology*, 45(12):5139–5146.

- McDonough, K.M., **Azzolina, N.A.**, Hawthorne, S.B., Nakles, D.V., and Neuhauser, E.F. 2010. A quantitative evaluation of the ability of chemical measurements to predict PAH-contaminated sediment toxicity to *Hyalella azteca*. *Environmental Toxicology and Chemistry*, 29:1545-1550.

- Neuhauser E.F., Ripp J.A., **Azzolina N.A.**, Madsen E.L., Mauro D.M., and Taylor T. 2009. MNA of MGP Tar MAHs & PAHs in Groundwater: A 14-Year Field Study. *Ground Water Monitoring & Remediation*, 29(3):66-76.

- Hawthorne S.B., St. Germain, R.W., and **Azzolina N.A.** 2008. Laser-induced fluorescence coupled with solid-phase microextraction for in-situ determination of PAHs in sediment pore water. *Environmental Science and Technology*, 42:8021-8026.

- Hawthorne S.B., **Azzolina N.A.**, and Finn J.T. 2008. Benzene is soil gas, indoor, and outdoor air; source identification based on tracer compounds and principal component analysis. *Environmental Forensics*, 9:1-11.

- Hawthorne S.B., **Azzolina N.A.**, Neuhauser E.F., and Kreitinger J.P. 2007. Predicting bioavailability of sediment PAHs to Hyalella azteca using equilibrium partitioning, supercritical fluid extraction, and pore water concentrations. *Environmental Science and Technology*, 41:6297-6304.

- **Azzolina N.A.**, Siegel D.I., Brower J., Samson S., Otz M., and Otz I. 2007. Can the HGM classification of small, non-peat forming wetlands distinguish wetlands from surface water geochemistry? *Wetlands*, 27(4):884-893.

F4: Flora modelling technical report

eco logical AUSTRALIA

North-east Pilliga Forest

Threatened Flora Modelling

Prepared for
Santos NSW (Eastern) Pty Ltd

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Contents

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Abbreviations

Abbreviation	Description
AIC	Akaike’s Information Criteria
CSG	Coal Seam Gas
ELA	Eco Logical Australia Pty Ltd
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GIS	Geographic Information System
GPS	Global positioning system
Ha	Hectares
NSW	New South Wales
Santos	Santos NSW (Eastern) Pty Ltd
TSC Act	NSW *Threatened Species Conservation Act 1995*

1 Introduction

This report was prepared to investigate threatened flora populations in the North-east Pilliga Forest for the Proponent. The scope of the 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.

Threatened flora listed under the *Threatened Species Conservation Act 1995* (TSC Act) and / or *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which are known to occur in the Narrabri Gas Project area include *Bertya opponens*, *Diuris tricolor* (Pine Donkey Orchid), *Lepidium aschersonii* (Spiny Peppercress), *Lepidium monoplocoides* (Winged Peppercress), *Myriophyllum implicatum*, *Polygala linariifolia* (Native Milkwort), *Pomaderris queenslandica* (Scant Pomaderris), *Pterostylis cobarensis* (Greenhood Orchid), *Rulingia procumbens* and *Tylophora linearis*.

Only a portion of these species were detected during targeted flora surveys in 2011 and 2012, namely *Diuris tricolor*, *Polygala linariifolia*, *Pterostylis cobarensis*, *Rulingia procumbens* and *Tylophora linearis*. These species are the subject of this report. Within the Narrabri Gas Project area, detailed mapping and population estimates have been previously developed for *Bertya opponens* and *Pomaderris queenslandica* (ELA, 2015a), while modelling for *Lepidium aschersonii*, *Lepidium monoplocoides*, *Myriophyllum implicatum* has not been undertaken due to insufficient records and poor seasonal conditions during the surveys in which they were detected.

The known distribution, habitat and ecology of the target species were limited prior to the 2011 and 2012 surveys. A summary of prior information is summarised in **Table 1**.

Table 1: Summary of known distribution, habitat and ecology of target species

Target species	Distribution, habitat and ecology (after (OEH, 2015b))
D. tricolor	Known to be sporadic on the western slopes of NSW, extending from south of Narrandera to the far north of NSW. The species is usually recorded from disturbed habitats and has been noted growing in large colonies, however singles and pairs have also been observed. It is typically found in sclerophyll forest on sandy soils
P. linariifolia	Known from northern NSW from separate populations located between the coast and far north-western NSW. Associated with sandy soils in dry eucalypt forest and woodland with a sparse understorey. It has been recorded as rare, sparse, occasional and common in populations.
P. cobarensis	Known from central and western NSW. Associated with eucalypt woodlands, open mallee or *Callitris* shrublands on low stony ridges in skeletal sandy-loam soils. Occurs as frequent to abundant (sometimes occasional) in usually very localised populations.
R. procumbens	Endemic to NSW, mainly confined to the Dubbo-Mendooran-Gilgandra regions, also the Pilliga and Nymagee. Grows in sandy sites often along roadsides. A pioneering species in disturbed habitats such as roadsides. Populations can be locally abundant.
T. linearis	Known from the central western region of NSW. Grows in dry scrub and open forest. Grows in dry scrub and open forest, and low altitude sedimentary flats in

Target species	Distribution, habitat and ecology (after (OEH, 2015b))
	dry woodlands. Very low number of confirmed populations in very low abundance.

Targeted flora surveys have been carried out in the study area (**Figure 1**) on two occasions. In 2011 surveys were conducted in order to identify whether threatened plants occurred within a previously proposed development footprint of well leases and associated gas gathering systems. The 2011 surveys were undertaken within an area of 6,450 hectares (ha). A broader survey of the surrounding locality with potential to support these threatened plants was carried out in 2012 over an area of 229,857 ha, excluding the 2011 survey area. The overall study area was 230,734 ha and was defined by buffering surveyed sites by 5 km (the mean distance between survey sites in 2012 was 3 km).

Regional scale vegetation mapping of the broad study area (ELA, 2013) includes eight Biometric vegetation types (**Table 2**). On ground surveys identified an additional two vegetation types NA160 and NA116. NA160 is similar to NA227 while NA116 is similar to NA124. The vegetation types surveyed and the corresponding biometric codes are presented in **Table 2**.

Table 2: Biometric vegetation types in the study area

Vegetation Type	Code
Blue-leaved Ironbark healthy woodland of the southern part of the Brigalow Belt South Bioregion	NA116
Brigalow - Belah woodland on alluvial often gilgaied clay soil mainly in the Brigalow Belt South Bioregion (Benson 35)	NA117
Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (Benson 141)	NA121
Brown Bloodwood - cypress - ironbark heathy woodland in the Pilliga region of the Brigalow Belt South Bioregion	NA124
Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (Benson 202)	NA141
Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland on Jurassic Sandstone of outwash plains (Benson 255)	NA160
Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)	NA179
Red Ironbark - Brown Bloodwood shrubby woodland of the Brigalow Belt South Bioregion	NA189
Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion	NA197
White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion	NA227

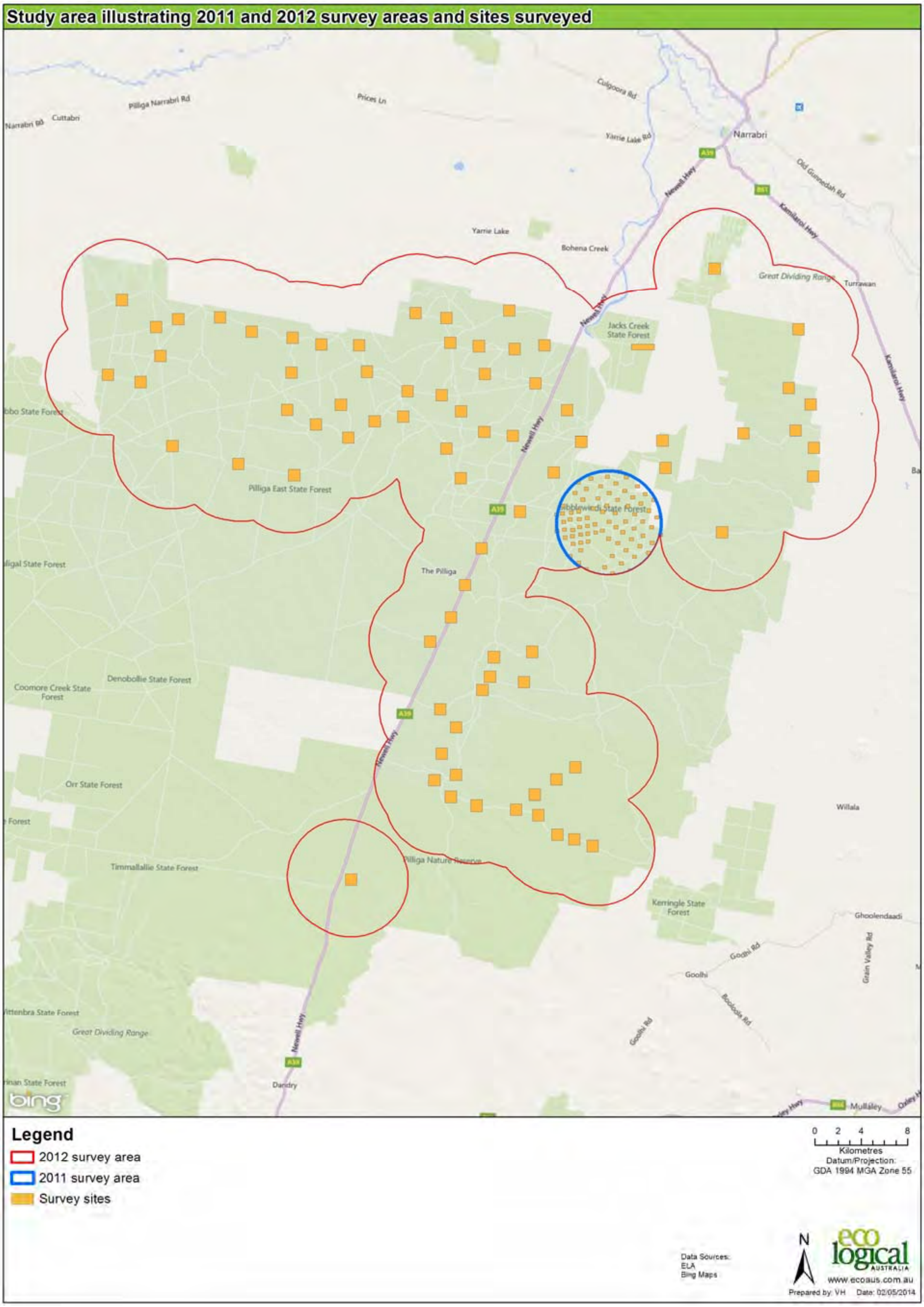

Figure 1: Study area illustrating 2011 and 2012 survey areas and sites surveyed

2 Methods

2.1 Survey design

2.1.1 2012 survey

A total of 79 sites were sampled in the 2012 survey (**Figure 1**) (ELA, 2012). Each site was 100 ha. Sites were selected in order to capture natural variability so covered a range of vegetation types, fire histories and logging histories and were located near roads for logistical reasons. Within each site between one and five strip-quadrats were surveyed giving a total of 306 quadrats. Strip-quadrats were located within a single biometric community vegetation type, and vegetation types were not necessarily the same within a site.

Each strip-quadrat was approximately 2500 m^2 (hereafter referred to as quadrats). The quadrats were 250 m long and were traversed by two botanists walking approximately 5 m apart and searching a total strip width of 10 m. The quadrats started at the edge of a road, went 100 m perpendicular to the road, then turned 50 m parallel to the road and returned 100 m back to the road. The number of threatened flora individuals were recorded within each quadrat as was the biometric vegetation type and vegetation characteristics (canopy, mid-storey and ground cover species) associated with the threatened flora sighting.

This quadrat design was used to maximise the encounter rate with the threatened plants, and therefore maximise sample size. The amount of time spent surveying each quadrat was approximately 2 person hours. The total number of quadrats in each vegetation type was generally proportional to the availability of that vegetation type. The sampling intensity was low due to the extensive size of the study area with a total of 0.033% of the area surveyed.

2.1.2 2011 survey

Flora surveys were carried out in 2011 within a study area of 6,450 ha with the purpose of locating threatened plants within a previously proposed development footprint of well leases and associated gas gathering systems. These surveys were not specifically designed to estimate abundance and distribution of threatened flora. Given: the lack of information on the distribution and abundance of these threatened species; the amount of survey effort (approximately 600 hours) in 2011; the fact that survey transects and location data for each threatened plant were recorded; and that two botanists surveyed an approximate 10 m wide strip (similar to the 2012 survey), it was decided that this data should be converted into a similar format to the 2012 survey and combined to give a larger sample size.

Quadrats were retrospectively established by dividing survey transects into 250 m lengths using a geographic information system (GIS). All threatened species recorded within a 10 m buffer of the transect were assigned to a quadrat, as was the predominant mapped vegetation type. The quality of the vegetation mapping for the 2011 survey area was higher because it had been validated in the field (ELA, 2015b). The total length of transects walked was 446.58 km, which was divided into 250 m long strip-quadrats. One quadrat at the end of a transect was only 78 m long, and four quadrats were 250.8 m long, these were excluded from analysis for mathematical reasons and attributes within these areas are similar to those in the retained areas, thus there was a total of 1783 quadrats. A random sample of one quarter of these quadrats was used in the analysis in order to reduce potential bias associated with the lack of spatial independence of quadrats. Each quadrat was assigned a random number (using a random number generator) and the 445 quadrats falling within the top 25% of random numbers were then used in analysis. The remaining quadrats were not included in the analysis.

The random sample of data was examined for potential bias by comparing the proportion of quadrats with threatened plants present included in the analysis with those that were excluded. There was no detectable bias associated with the random sample as the proportion of quadrats was the same order of magnitude for all records included and excluded from analyses.

The random quadrats were located in five different biometric vegetation types plus cleared land, and the total proportion of the area surveyed was 1.72%. The 2011 survey included cleared land, and cleared land is recorded to have been sampled the most intensively of all vegetation types. This is likely an artefact of many records occurring close to roads and geographic position system (GPS) error. The vegetation type NA141 (Fuzzy Box on loams in the Nandewar Bioregion and northern Brigalow Belt South Bioregion (Benson 202)) was represented in the 2011 survey but was absent from the 2012 survey and regional vegetation type mapping. This vegetation type is most similar to NA197. Given that vegetation type NA141 was not mapped, all quadrats in this vegetation type were assigned to vegetation type NA197.

2.1.3 Combining 2011 and 2012 data

Plant density and abundance estimations were made by combining the 2011 and 2012 data (see Section **2.3**). An estimate of the area of each vegetation type across the entire study area was required in order to estimate plant abundance. The total area of each biometric vegetation type within the study area was calculated in a GIS. The vegetation type data has been mapped at a regional scale and some quadrats were assigned to vegetation types that are not represented on the maps, but are very close to vegetation types that are mapped. These include NA116 which is close to NA124 and NA160 which is close to NA227. The area of the unmapped vegetation types and its close type were calculated by assigning the vegetation type a percentage of the area from regional maps based on the proportion of that vegetation type sampled.

The combined survey sampled eight of the ten vegetation types with the unsampled vegetation types representing less than 0.5% of the total area (**Table 3**). A proportion of the study area was not mapped as biometric vegetation types. These included derived grasslands, water storage, wetlands and marshes, cropping, infrastructure and urban areas. These areas were included in the Other/Unknown category (**Table 3**). Furthermore, some of the quadrats were recorded from either unknown (2012 data) or cleared (2011 data) vegetation types. The cleared vegetation type typically refers to the edge of a vegetation type such as on a roadside. A total of 751 quadrats are included in the data set, incorporating data from both 2011 and 2012. Sampling intensity was at about 0.08% which is low but higher levels are difficult to achieve over such a large area. The most common vegetation type, NA227, was sampled the most frequently, and survey effort was generally related to area of vegetation types.

Table 3: Summary of survey effort and vegetation types for the 2011 and 2012 surveys combined

Vegetation Type	# quadrats	Area Surveyed		Area of vegetation within survey area (ha)	Sampling intensity (%)
		m^2	ha		
NA116	7	17500	1.8	9,572.8	0.02
NA117	0	0	0.0	957.7	0.00
NA121	3	7500	0.8	9,538.4	0.01
NA124	156	388750	38.9	50,257.3	0.08
NA160	21	51250	5.1	11,678.3	0.04
NA179	21	52500	5.3	7,375.9	0.07

Vegetation Type	# quadrats	Area Surveyed		Area of vegetation within survey area (ha)	Sampling intensity (%)
		m^2	ha		
NA189	46	113750	11.4	29,732.0	0.04
NA197	62	152500	15.3	14,893.2	0.10
NA219	0	0	0.0	4.6	0.00
NA227	330	821250	82.1	78,154.8	0.11
Other/Unknown*	105	262500	26.3	18,589.2	0.14
Grand Total	**751**	**1867500**	**186.8**	**230,734.1**	**0.08**

2.2 Plants associations with vegetation communities

The number of individual plants from vegetation communities was summarised by summing the counts of each threatened plant species by vegetation type. Data are presented separately for 2011 and 2012.

The proportion of quadrats occupied by a species in each vegetation community for both years combined was calculated by assigning the species as present or absent from a quadrat (using 0 for absent and 1 for present), and then summing the number of quadrats with the species present and presenting as a proportion of total number of quadrats.

2.3 Plant density and abundance

The low number of observations of quadrats with plants results in major kurtosis (non-parametric) distribution in the data set which is problematic for use of statistical analysis techniques and frequency distribution models. To enable statistic analysis of the data, the data kurtosis was managed by taking a two-part approach and treating the zero data separately (Cunningham & Lindenmayer, 2005). Firstly a naive estimate of the proportion of quadrats occupied by the species in each vegetation type was calculated (see **Section 2.2**). Secondly, mean plant density and variance were calculated by fitting frequency distribution models to plant density data for quadrats where plants were present. Abundance was then estimating by multiplying the calculated mean density (and variance) by the proportion of the vegetation type occupied.

For quadrats where species were present, mean density and 95% confidence intervals were estimated by fitting four distribution models to the data in JMP (Version 11.1): Normal, Exponential, Poisson and Gamma Poisson (SAS Institute Inc, 2014). The Gamma Poisson distribution is equivalent to a Negative Binomial if the estimate for α is an integer (SAS Institute Inc, 2014). The preferred model was determined by goodness-of-fit testing. Since the Poisson functions are a discrete fit and the other two are continuous, it was not possible to compare the models using Akaike's Information Criteria (AIC) values. Therefore, the model with the highest p-value was selected. The goodness-of-fit test for the Normal model was the Shapiro-Wilk W test, for the Exponential model was the Kolmogorov's D test and for the Poisson models was the Pearson Chi-Squared test (SAS Institute Inc, 2014).

Plant densities per quadrat were calculated separately for each species. When sample sizes were low, data were pooled across all vegetation types. Additional distribution models were applied to vegetation types where sample sizes were larger than 10. Finally, plant densities were converted into plants per hectare where plants were present. Vegetation type mapping used for analysis did not include 'cleared' so it was not treated independently, but incorporated with 'All Vegetation'.

A test was undertaken to determine whether taking the two part approach and treating the zero data separately introduced bias. This was completed for each species. The ratio of quadrats without plants present (i.e. 0) in a vegetation community to the total number of 0 quadrats across all vegetation communities was calculated and compared to the ratio of quadrats with a species present (i.e. 1) in a vegetation community to the total number of 1 quadrats across all vegetation communities. Then an F-test ($\alpha = 0.05$) was performed to test whether the variance of the two datasets was equal. The variance was found to be equal for all species therefore it is assumed that the approach did not introduce bias.

3 Results

3.1 Plant associations with vegetation communities

3.1.1 2012 survey

The 2012 survey successfully located 1,333 threatened plants, the majority of which were *Pterostylis cobarensis* and *Rulingia procumbens* with other species far less frequently observed (**Table 4**). The majority of plants (primarily *Rulingia procumbens*) were found within the NA189 vegetation community (Red Ironbark - Brown Bloodwood shrubby woodland of the Brigalow Belt South Bioregion) which covers 12.8% of the study area (see **Table 3**).

No threatened plants were found in vegetation types NA121 (Broombush shrubland of the sand plains of the Pilliga region, subtropical sub-humid climate zone (Benson 141)) or NA197 (Rough-barked Apple riparian forb/grass open forest of the Nandewar Bioregion) (**Table 4**). This may be an artifact of small sample size for NA121 (only 3 quadrats), and possibly for NA197 (24 quadrats). Threatened plants have been recorded in these vegetation types during previous surveys (ELA, 2015a).

The vegetation type NA179 (Pilliga Box - Poplar Box- White Cypress Pine grassy open woodland on alluvial loams mainly of the temperate (hot summer) climate zone (Benson 88)) did not support very high densities of threatened plants.

A high degree of aggregation of individuals within a species was observed, notably for *R. procumbens* where over 300 plants were found in one quadrat, but plants were only found in a total of 6 quadrats. *Polygala linariifolia* also showed a strong pattern of aggregation with 10 plots containing between 20 and 30 individuals out of a total of 9 plots with the species present.

Table 4: Number of individuals of each species observed in each vegetation type in 2012

Vegetation Type	Number of individuals of each flora species				
	Tylophora linearis	*Polygala linariifolia*	*Pterostylis cobarensis*	*Diuris tricolor*	*Rulingia procumbens*
NA116	1	0	2	0	0
NA121	0	0	0	0	0
NA124	1	0	50	0	159
NA160	4	3	172	0	0
NA179	3	0	5	0	0
NA189	7	0	0	0	486
NA197	0	0	0	0	0
NA227	17	24	395	4	0
Unknown	0	0	0	0	0
Grand Total	**33**	**27**	**624**	**4**	**645**

3.1.2 2011 survey

The randomly allocated quadrats from the 2011 survey identified a total of 171 threatened plants with observations dominated by *Pterostylis cobarensis* (**Table 5**). No *Rulingia procumbens* were observed in the 2011 survey on transects which is in contrast to the 2012 survey. *Tylophora linearis* and *Pterostylis cobarensis* were both recorded in 'cleared' areas. These areas were typically close to roads on the margins of vegetation communities.

Table 5: Number of individuals of each species observed in each vegetation type in 2011

Vegetation Type	Number of individuals of each flora species			
	Tylophora linearis	*Polygala linariifolia*	*Pterostylis cobarensis*	*Diuris tricolor*
Cleared	18	0	16	0
NA124	5	7	3	5
NA141	0	0	0	0
NA179	0	0	0	0
NA197	2	0	2	0
NA227	31	6	76	0
All	**56**	**13**	**97**	**5**

3.1.3 Occupancy of quadrats by plants

Threatened plant presence varied between vegetation types (**Table 6**). All of the target species were found in NA124, while none were found in NA121 or NA141. The geographical distribution of *Diuris tricolor* and *Rulingia procumbens* were limited to only two vegetation types while *Tylophora linearis* and *Pterostylis cobarensis* were found across a broader suite of vegetation types (**Table 6**). No plants were found in the three quadrats with vegetation type 'Unknown' so they were excluded from further analysis.

Occupancy of quadrats was typically very low (less than 14%) for all species across all vegetation types with the exception of *Pterostylis cobarensis* which was found in most quadrats within NA160 (**Table 6**).

Table 6: Occupancy of vegetation types by threatened plants

Vegetation type	# quadrats	Proportion (%) of quadrats with plants present				
		T. linearis	*P. linariifolia*	*P. cobarensis*	*D. tricolor*	*R. procumbens*
Cleared	102	10.784	0.000	6.863	0.000	0.000
NA116	7	14.286	0.000	14.286	0.000	0.000
NA121	3	0.000	0.000	0.000	0.000	0.000
NA124	156	1.282	1.282	3.846	2.564	1.282
NA160	21	14.286	9.524	71.429	0.000	0.000
NA179	21	9.524	0.000	14.286	0.000	0.000
NA189	46	4.348	0.000	0.000	0.000	8.696
NA197	62	3.571	0.000	1.786	0.000	0.000

Vegetation type	# quadrats	Proportion (%) of quadrats with plants present				
		T. linearis	*P. linariifolia*	*P. cobarensis*	*D. tricolor*	*R. procumbens*
NA227	330	9.697	1.515	13.939	0.606	0.000
TOTAL	**748**	**7.324**	**1.198**	**10.519**	**0.799**	**0.799**

3.2 Plant densities and abundance

3.2.1 *Tylophora linearis*

A total of 89 *T. linearis* individuals were identified in the surveys (**Table 4**, **Table 5**). These individuals were located in 55 of the 748 surveyed quadrats, which represents 7.3% of sampled quadrats overall. *T. linearis* occurred in the highest proportion of quadrats in the NA116 and NA160 vegetation communities, closely followed by Cleared, NA179 and NA227 (**Table 6**).

The density of *T. linearis* in quadrats where it was present was calculated to be 6.5 plants per hectare 95% CI: 5.0 – 8.5) (**Table 7**). The model that fit the *T. linearis* frequency distribution the best overall was the fitted exponential, though the fit was very weak (Kolmogorov's D, p = 0.01). There were sufficient records in NA227 to conduct a separate analysis for this vegetation type but again the fit was weak, and the resulting estimates were similar, therefore the model for 'All Vegetation Types' was used for all abundance estimates.

Table 7: Models used to estimate densities of *Tylophora linearis* in quadrats where the species was present

Veg Type	Sample size	Best Model		Plants per quadrat (2,500m^2) where plants present			Plants per hectare where plants present		
		Type	Fit (*p* value)	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
All	55	Exponential	0.01	1.618	1.256	2.133	6.473	5.025	8.534
NA227	32	Exponential	0.01	1.500	1.115	1.965	6.0	4.459	7.861

An estimated 109,376 (95% CI: 84,915 – 144, 206) *T. linearis* occur within the study area with almost half estimated to occur within the vegetation community NA227 (**Table 8**). The confidence intervals of estimates should be used with caution because the data did not fit the frequency distributions well.

Table 8: Estimated area of vegetation types occupied by and abundance (± 95% CI) of *Tylophora linearis* within the study area

Vegetation type	*Tylophora linearis*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA116	1,368	8,852	6,872	11,671
NA124	644	4,171	3,238	5,499
NA160	1,668	10,799	8,384	14,237
NA179	702	4,547	3,530	5,995
NA189	1,293	8,367	6,496	11,032

Vegetation type	*Tylophora linearis*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA197	532	3,443	2,673	4,539
NA227	7,579	49,054	38,084	64,676
TOTAL	**16,898**	**109,376**	**84,915**	**144,206**

3.2.2 Polygala linariifolia

A total of 40 *P. linariifolia* individuals were identified in the surveys (**Table 4**; **Table 5**). These individuals were located in nine of the 748 surveyed quadrats, which represents 1.2% of sampled quadrats. *P. linariifolia* only occurred in three vegetation communities, NA124, NA160 and NA227 (**Table 6**).

The frequency distribution of number of plants per quadrat in quadrats where plants were present was best described by the Gamma Poisson model. The density of *P. linariifolia* in quadrats where it was present was calculated to be 19.5 plants per hectare (95% CI: 9.7 – 33.5) (**Table 9**). Thus, *P. linariifolia* occurs very infrequently, but where it does occur, it is frequently clumped.

Table 9: Models used to estimate densities of *Polygala linariifolia* in quadrats where the species was present

Veg Type	Sample size	Best Model		Plants per quadrat (2,500m^2) where plants present			Plants per hectare where plants present		
		Type	Fit (*p* value)	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
All	9	Gamma Poisson	0.6196	4.867	2.442	8.380	19.468	9.768	33.520

Similar numbers of *P. linariifolia* occurred within the NA160 and NA227 vegetation types, with a total estimate of 53, 831 (95% CI: 27,010 – 92,687) plants occurring within the study area (**Table 11**).

Table 10: Estimated area of vegetation types occupied by and abundance (± 95% CI) of *Polygala linariifolia* within the study area

Vegetation type	*Polygala linariifolia*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA124	644.32	12,544	6,294	21,598
NA160	1,112.22	21,653	10,864	37,282
NA227	1,184.16	23,053	11,567	39,693
TOTAL	**2,765.12**	**53,831**	**27,010**	**92,687**

3.2.3 *Pterostylis cobarensis*

A total of 721 *P. cobarensis* individuals were identified in the surveys (**Table 4**; **Table 5**). These individuals were located in 79 of the 748 surveyed quadrats which represents 10.5% of quadrats overall. *P. cobarensis* occurred in all vegetation types except NA121 and NA189 and was commonly found in NA160 (**Table 6**). *P. cobarensis* showed patterns of aggregation with 19 quadrats having more than 20 individual plants.

The density of *P. cobarensis* in quadrats where it was present was calculated to be 36.5 (95% CI: 29.5 – 45.9) plants per hectare when all data were pooled and using the Exponential model. These confidence intervals should be used with caution due to the weakness of the model fit (**Table 11**). When records for NA160 were analysed separately, the Gamma Poisson model provided a much stronger fit, and densities estimates were higher though this was not statistically significant as shown by the overlap in 95% confidence intervals). When records for NA227 were analysed, the Gamma Poisson was also the model with the best fit, thought the fit wasn't nearly as strong, and the density estimates were even higher, though not significantly.

Table 11: Models used to estimate densities of *Pterostylis cobarensis* in quadrats where the species was present

Veg Type	Sample size	Best Model		Plants per quadrat (2,500m^2) where plants present			Plants per hectare where plants present		
		Type	Fit (p value)	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
All	79	Exponential	0.01	9.126	7.378	11.474	36.504	29.512	45.896
NA160	15	Gamma Poisson	1.000	11.467	7.581	18.243	45.868	30.324	72.972
NA227	46	Gamma Poisson	0.025	13.419	10.136	17.263	53.676	40.544	69.052

Given the superior model fit for NA160 and NA227, abundance estimates for these vegetation types were estimated using the specific models for those vegetation types. Abundance estimates were highest in these two vegetation types with 382,615 (95% CI: 252,952 – 608,706) individual *P. cobarensis* estimated to occur within NA160 within the study area and 594,763 (95% CI: 441,699 – 752,273) individual *P. cobarensis* estimated to occur within NA227 (**Table 12**). Overall within the study area, there are estimated to be 886,011 (95% CI: 716,304 – 1,113,971) individual *P. cobarensis*.

Table 12: Estimated area of vegetation types occupied by and abundance (± 95% CI) of *Pterostylis cobarensis* within the study area

Vegetation type	*Pterostylis cobarensis*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA116	1,368	49,921	40,359	62,765
NA124	1,933	70,561	57,046	88,716
NA160	8,342	382,615	252,952	608,706
NA179	1,054	38,464	31,097	48,360

Vegetation type	*Pterostylis cobarensis*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA197	266	9,708	7,849	12,206
NA227	10,894	584,763	441,699	752,273
ALL	**24,272**	**886,011**	**716,304**	**1,113,971**

3.2.4 Diuris tricolor

A total of nine *D. tricolor* individuals were identified in the surveys (**Table 4**, **Table 5**). These individuals were located in six of the 748 surveyed quadrats, which represents a very small 0.8% of all quadrats, and was only observed in two vegetation types, NA124 and NA227 (**Table 6**).

The density of *D. tricolor* in quadrats where it was present was calculated to be 6.0 plants per hectare (95% CI: 3.1 – 11.5) (**Table 13**). The model that fit the *D. tricolor* frequency distribution the best was the Poisson model, and the fit was good, though the sample size was small (6).

Table 13: Model used to estimate densities of *Diuris tricolor* in quadrats where the species was present

Veg Type	Sample size	Best Model		Plants per quadrat (2,500m^2) where plants present			Plants per hectare where plants present		
		Type	Fit (p value)	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
All	6	Poisson	0.634	1.500	0.780	2.883	6	3.12	11.532

There was estimated to be 11, 060 *D. tricolor* across the study area (95% CI: 5,751 – 21,258) (**Table 14**).

Table 14: Estimated area of vegetation types occupied by and abundance (± 95% CI) of *Diuris tricolor* within the study area

Vegetation type	*Diuris tricolor*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA124	1,289	7,732	4,021	14,861
NA227	474	2,842	1,477.84	5,462
All	**1,843**	**11,060**	**5,751**	**21,258**

3.2.5 Rulingia procumbens

A total of 645 *R. procumbens* were identified in the surveys (**Table 4**, **Table 5**). These individuals were located in 6 of the 748 surveyed quadrats which represents only 0.8% of all quadrats present. *R. procumbens* was only found in two vegetation communities NA124 and NA189 (**Table 6**). Thus, it is very highly spatially aggregated in the landscape.

The density of *R. procumbens* in quadrats where it was present was high with 430 plants per hectare, but there was a broad range of confidence around this value (95% CI: 163 – 1,535) (**Table 15**). The model that best fit the data was the Gamma Poisson frequency distribution and the fit was strong. There were not a sufficient number of records to estimate densities for separate vegetation types.

Table 15: Models used to estimate densities of *Rulingia procumbens* in quadrats where the species was present

Vege Type	Sample size	Best Model		Plants per quadrat (2,500m^2) where plants present			Plants per hectare where plants present		
		Type	Fit (p value)	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
All	6	Gamma Poisson	1.000	107.5	40.624	383.696	430	162.5	1,534.8

The highest abundance estimates for *R. procumbens* are within vegetation type NA189 where the highest proportion of quadrats that were occupied by the species. The estimated abundance in this vegetation type is 1,111,717 plants per hectare (95% CI: 420,115 – 3,968,014). This estimate is higher than for all vegetation types combined because the proportion of all vegetation types with *R. procumbens* was very low. This differences are not significant as shown by the large overlap in the 95% confidence intervals.

Table 16: Estimated area of vegetation types occupied by and abundance (± 95% CI) of *Rulingia procumbens* within the study area

Vegetation type	*Rulingia procumbens*			
	Estimated area occupied (ha)	Abundance estimate	lower 95% CI	Upper 95% CI
NA124	644	277,060	104,700	988,899
NA189	2,585	1,111,717	420,115	3,968,014
ALL	**1,843**	**792,668**	**299,548**	**2,829,243**

4 Discussion

4.1 *Tylophora linearis*

The plant surveys conducted as part of this project identified a new meta-population of *T. linearis* with the nearest previous known record located approximately 78 km to the north east of the study area (OEH, 2015a). During this survey, *T. linearis* was recorded in a broad range of vegetation types often associated with a *Eucalyptus crebra* (Narrow-leaved Ironbark) canopy, shrubby mid-storey dominated by *Callitris glaucophylla* (White Cypress Pine), *Allocasuarina luehmannii* (Bull Oak) and a sparse grassy groundcover. The individuals were often found within *Gahnia aspera* (Rough Saw-sedge), around logs or the base of canopy regrowth. Sites often had evidence of disturbance from forestry, track work or recent fire.

Populations were found to be very small with the majority of records for one plant and a maximum of 6 plants being observed in one quadrat. This supports the previous understanding that the species does not occur in aggregations and occurs in very low abundance (OEH, 2015b),

The fit of frequency distribution models *T. linearis* was weak despite the relatively high sample size. As such abundance estimates and confidence intervals should be used with caution. Nonetheless, the abundance estimation indicates that there is likely to be a substantial population of *T. linearis* within the study area.

4.2 *Polygala linariifolia*

The plant surveys conducted as part of this project identified a new meta-population of *P. linariifolia*. The nearest known record of *P. linariifolia* was approximately 122 km to the north-east of the study area (OEH, 2015a). Given the ephemeral nature of the species, it is thought that the presence of individuals during the survey was correlated with recent flood events and potentially fire.

Observations of the population of *P. linariifolia* from December 2010 show great fluctuations in population size and distribution (ELA, 2015a). It is likely that the species is ecologically associated with flood events for dispersal. Significant flooding in November/December 2010 may have widely distributed the propagules of this species throughout the project area, leading to the large numbers of individuals recorded in December 2010. Due to the nature of the Pilliga Forests, it is not inconceivable that *P. linariifolia* may also be a fire ephemeral species. Most of the individuals observed were considered to be annual only, with only those individuals in sheltered situations persisting for more than one season. *P. linariifolia* has been observed flowering/fruiting in January, April and October in the Pilliga by ELA.

During the 2012 survey, *P. linariifolia* was recorded in White Cypress Pine - Bulloak - Ironbark Woodland and Mugga Ironbark - Pilliga Box - pine- Bulloak shrubby woodland. It was associated with a dense mid-storey of *C. glaucophylla* and/or *A. luehmannii* and a grassy understorey. This is in contrast to previous surveys where *P. linariifolia* has been observed in a range of vegetation types, mostly characterised by a grassy understorey.

P. linariifolia was recorded as single plants, but also in groups of 5, 6 and 21 in the survey. This is consistent with other records where it has been recorded as rare, sparse, occasional and common in populations.

The fit of abundance models was strong for *P. linariifolia* therefore population estimates can be used with relative confidence.

4.3 *Pterostylis cobarensis*

There was one record for *P. cobarensis* near the study area prior to the survey, with the remainder of records located at least 200 km to the south-west (OEH, 2015a). This survey identified an additional 721 individuals for the Pilliga area.

In this study, *P. cobarensis* was recorded in a broad range of vegetation types but was most frequently observed in Mugga Ironbark - Pilliga Box - pine- Bulloak Shrubby Woodland. It was most often associated with a dense mid-storey of *C. glaucophylla* and/or *A. luehmannii*. The groundcover was characterised by low shrub, grass and herb cover and high leaf litter with sandy soils. *P. cobarensis* was occasionally recorded within unburnt mosaics that remained within areas that were burnt in a large bushfire in 2006/2007.

Most records were of small groups of individuals (1 – 8), but larger aggregations were found with up to 56 individuals recorded in one quadrat. This pattern of distribution is consistent with previous records for the species (OEH 2014).

The fit of the frequency distribution model for all vegetation types was weak despite the relatively high sample size. The fit was far stronger when analysed by vegetation type for the two vegetation types that *P. cobarensis* occurred most frequently in (NA160 and NA227).

4.4 *Diuris tricolor*

There were no previous records for *Diuris tricolor* for the study area. *D. tricolor* was only recorded from 6 quadrats in the survey. Due to the relative scarcity of *D. tricolor* in the locality, it is difficult to associate certain physiographical/ecological features with this species. During this survey, *D. tricolor* was recorded in White Cypress Pine – Bulloak – Ironbark Woodland dominated by *E. crebra*. The midstorey was shrubby dominated by a combination of *C. glaucophylla A. luehmannii* and *Callitris endlicheri* (Black Cypress Pine) at the three sites. The groundcover was predominantly sparse grasses and occasionally shrubby. Evidence of a low intensity fire and dense *E. crebra* regrowth was recorded at two of the sites.

Records were for one, two or three individuals within a quadrat. This suggests that *D. tricolor* does not form larger aggregations in the study area.

The fit of the frequency distribution model was good despite the low sample size. The small sample size resulted in a high co-efficient of variation in the data.

4.5 *Rulingia procumbens*

R. procumbens was known from a site close to the study area prior to survey (OEH, 2015a). The survey identified an additional 645 individuals at six locations.

During this survey, *R. procumbens* was recorded in Brown Bloodwood - Cypress - Ironbark Heathy Woodland and Red Ironbark - Brown Bloodwood Shrubby Woodland. It was mainly found along roadsides although large numbers were also found in areas with dense low shrubs dominated by *Acacia pilligaensis* (Pilliga Wattle) *and Chloanthes parviflora* with evidence of recent fire (within past five years). Many of the locations were observed to be directly downslope of rocky hills on red sand, although this was not a consistent determiner of presence. The location of individuals along roadsides is consistent with previous records (OEH 2014). However, the observations downslope of rocky hills on red sand has not been previously noted.

Populations were highly aggregated in this study which is consistent with previous observations of the species being locally abundant (OEH 2014).

The fit of the frequency distribution model was good despite the low sample size. The small sample size resulted in a high co-efficient of variation in the data.

4.6 Limitations

Abundance estimates for the threatened flora in this report used a two-pronged approach because of the dominance of zero data points and the associated kurtosis in the data set. Zero-inflated data is a common challenge when working with rare species, though these are the species we often want to know the most about.

The strip-quadrats used during the survey were long and thin and were not marked out with measuring tapes or pegs because this would have at least doubled the time taken to do the survey. This approach to quadrat counts can lead to counting errors (Krebs, 1999). The typical error that occurs is that plants that are outside the quadrat are included leading to a positive bias because people have a tendency to want to include all observations, though this effect may have been counter acted by failure to detect individuals.

The first stage of estimating the density and abundance of the threatened plants involved estimating the proportion of quadrats occupied by the species. It is noted that this may be an underestimate due to imperfect detection and that a more precise estimate could have been achieved if quadrats were surveyed more than once (MacKenzie et al., 2002). Surveying quadrats more than once would have doubled the survey time and was not considered feasible.

Density estimates and 95% confidence intervals were presented as part of this study. These estimates were based on small sample sizes for *P. linariifolia* and *R. procumbens*, so both estimates of means and 95% confidence intervals should be used with caution. In addition, a good fit of frequency distributions models was not achieved for several species (e.g. *T. linearis*). While the confidence intervals may not be precise, the level of effort undertaken and the large size of the area investigated provides the best estimates for threatened species populations in the north-east Pilliga Forest to date.

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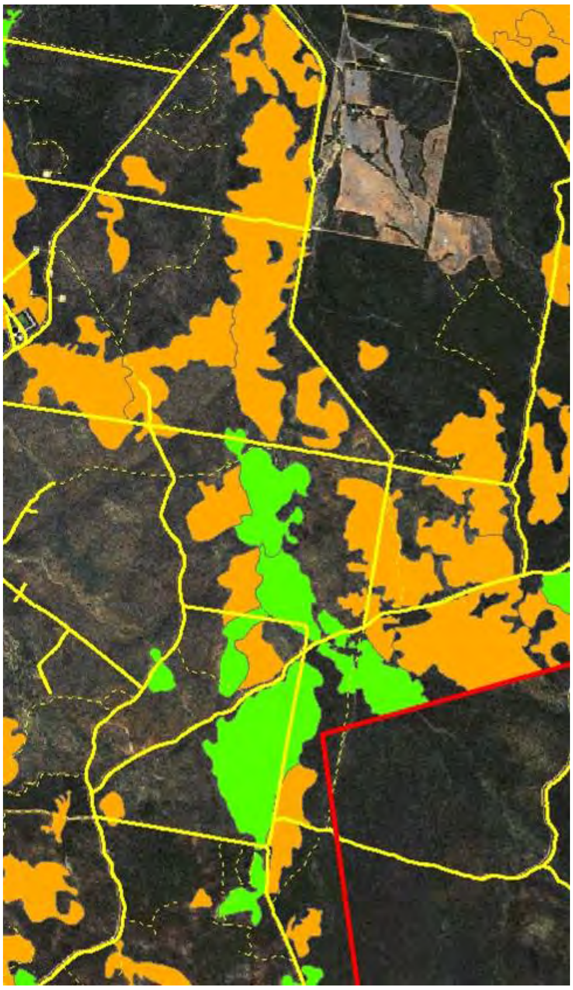
F5: Pilliga Mouse habitat technical report

Narrabri Gas Project

Pilliga Mouse Habitat Assessment

Prepared for
Santos NSW (Eastern) Pty Ltd

October 2015



This report should be cited as 'Eco Logical Australia 2015. *Narrabri Gas Project – Pilliga Mouse Habitat Assessment*. Prepared for Santos NSW (Eastern) Pty Ltd.'

Contents

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Abbreviations

Abbreviation	Description
API	Aerial Photograph Interpretation
CHM	Vegetation Canopy Height Model
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GIS	Geographic Information System
LiDAR	Light Detection and Ranging
TSC Act	NSW *Threatened Species Conservation Act 1995*

Executive Summary

Eco Logical Australia was engaged by the Proponent to prepare a Pilliga Mouse habitat model for the Narrabri Gas Project which covers approximately 95,077 ha in the northeast Pilliga Forest (the study area). The Pilliga Mouse habitat model will form part of the base data to be assessed as part of the ecological assessment for the Environmental Impact Statement for the Narrabri Gas Project.

Pseudomys pilligaensis (Pilliga Mouse) is a small native murid rodent which is restricted to an isolated area of low-nutrient deep sand which has long been recognised as supporting distinctive vegetation (Pilliga Forest).

To identify areas of primary and secondary Pilliga Mouse habitat within the study area, a desktop assessment followed by a field habitat validation assessment was undertaken. Potential Pilliga Mouse habitat was initially identified using vegetation Canopy Height Modelling in conjunction with Aerial Photograph Interpretation in a Geographic Information System. Areas within the Canopy Height Modelling indicative of Pilliga Mouse habitat (i.e. areas with a dense low shrub cover) were mapped and flagged for further field validation.

A field validation survey assessed the accuracy of the initial habitat modelling as well as mapping new areas of habitat not originally identified. Rapid field assessments were taken at each site considered to constitute potential Pilliga Mouse habitat with vegetation type, dominant species, shrub cover and soil type recorded. Based on the field assessment, the habitat modelling was further refined.

The Pilliga Mouse habitat model was developed to provide a greater understanding of the potential distribution of Pilliga Mouse habitat. The Pilliga Mouse habitat model will be integrated into the Ecological Sensitivity Analysis to minimise potential impacts on the Pilliga Mouse during planning phases of natural gas development in the Pilliga Forest. The model may also be incorporated into the Proponents' Geographic Information System to help inform planning decisions.

1 Introduction

Eco Logical Australia (ELA) was engaged by the Proponent to prepare a *Pseudomys pilligaensis* (Pilliga Mouse) habitat model for the Narrabri Gas Project which covers approximately 95,077 ha in the northeast Pilliga Forest (**Figure 1**). The Pilliga Mouse habitat model will form part of the base data to be assessed as part of the ecological assessment for the Environmental Impact Statement (EIS) for the Narrabri Gas Project.

The Pilliga Mouse is a small native murid rodent which is restricted to an isolated area of low-nutrient deep sand which has long been recognised as supporting distinctive vegetation (Pilliga Forest). The Pilliga Mouse is listed as 'Vulnerable' under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A number of studies have been undertaken into the Pilliga Mouse since its discovery in the early 1980's, however detailed habitat mapping is not available for this species.

It is important to note that the Pilliga Mouse is now considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed and Ford 2007; Ford 2008, as cited in SEWPaC 2012). It is important to note that this taxonomic change has not yet been formally recognised under the EPBC Act, hence this report considers the Pilliga Mouse as currently listed.

1.1 Aims and objectives

The aim of this project was to develop a habitat model for Pilliga Mouse that identifies areas of primary and secondary habitat within the study area. Primary Pilliga Mouse habitat is considered more likely to be inhabited by the Pilliga Mouse on a more permanent basis, while the secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years.

This project will provide a greater understanding of the potential distribution of Pilliga Mouse habitat and assist in minimising the impacts of natural gas development on this species. The specific objectives of this project were to:

- Undertake a desktop assessment using Canopy Height Model data in conjunction with Aerial Photograph Interpretation in a Geographic Information System using ArcGIS 10.2 to initially map areas of potential Pilliga Mouse habitat and develop a draft Pilliga Mouse habitat model.
- Assess the accuracy of the draft model during a field validation survey, and highlight areas not identified in the initial assessment.
- Refine the Pilliga Mouse habitat model based on the results of the field validation survey.
- Develop a final Pilliga Mouse habitat model with areas of primary and secondary habitat identified.

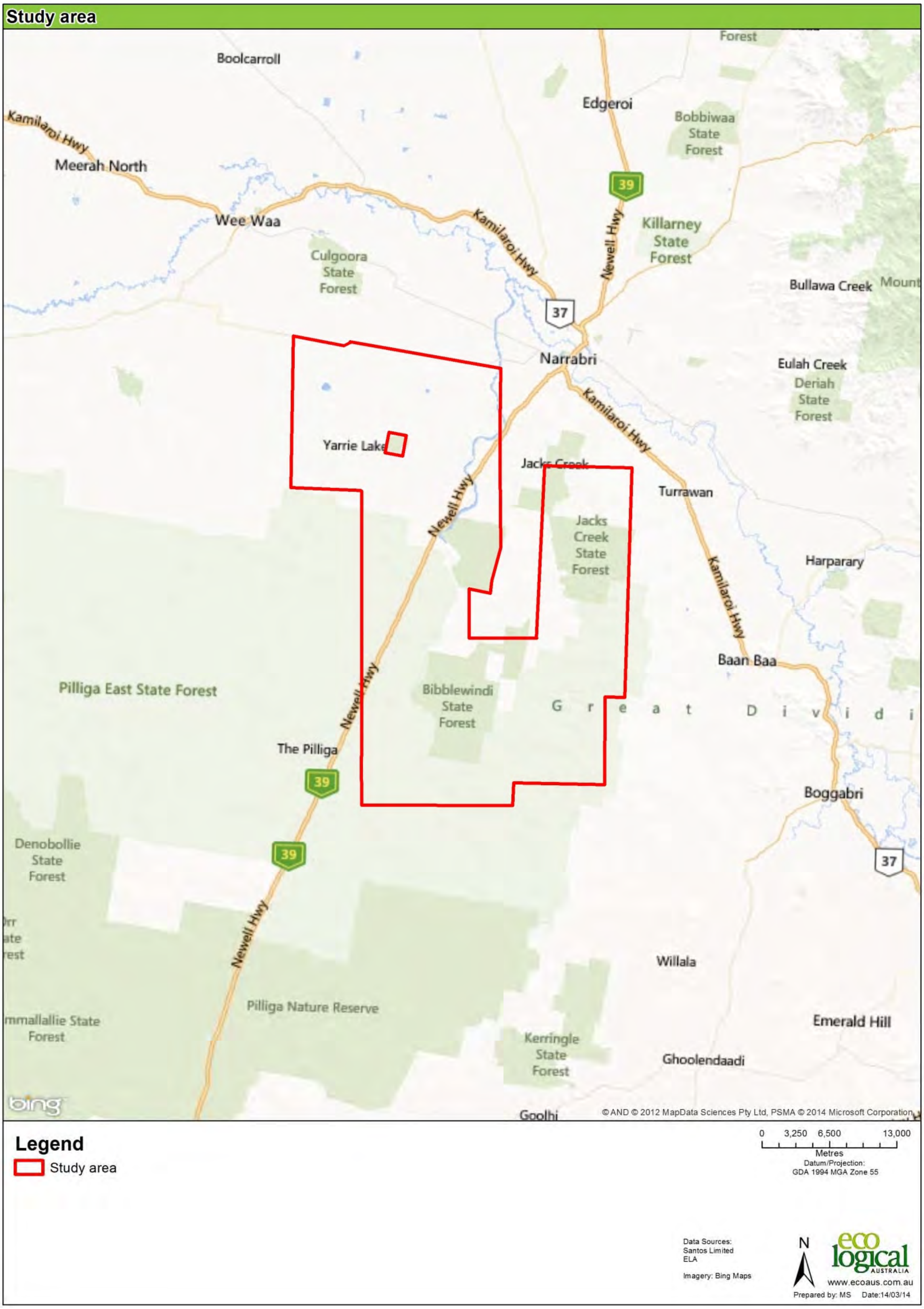

Figure 1: Study area

2 Methodology

2.1 Pilliga Mouse ecology

The Pilliga Mouse is mostly restricted to the Pilliga Forest, with a few records outside the Pilliga from Binnaway Nature Reserve (approximately 30 km southeast of Coonabarabran) and Bebo State Forest (approximately 230 km northeast of Narrabri) (OEH 2013a, NPWS 2002, Jarman & Green 2000). Its distribution is sparse and thought to temporally fluctuate. The reasons for the irruptive population phases are unknown but may relate to recent fire history and high rainfall periods (Tokushima et al. 2008b).

The irruptive behaviour of the Pilliga Mouse has produced a range of population size estimates. Population size has been estimated to be approximately 50,000 to 100,000 during irruptive periods (Paull & Milledge 2011). Peak density has been calculated at 15-90 Pilliga Mice / ha in comparison to low density calculated at 0-5 Pilliga Mice / ha (Tokushima et al. 2008a, SEWPaC 2013).

Habitat requirements for Pilliga Mouse are not fully understood and are likely to vary with seasonal conditions. The current understanding of this species suggests that primary habitat patches support this species within the Pilliga, playing an important role as refuge habitat during times of population contraction. A wider range of habitat is used for dispersal during a population irruption when environmental conditions are favourable (Tokushima et al. 2008a). The longest lineal distance that the Pilliga Mouse has been recorded travelling between successive captures is approximately 180 m, however other related species have been shown to move in the order of 400 km over short timeframes (Tokushima and Jarman 2008).

Primary habitat has been associated with low-nutrient deep sand supporting a relatively high low-shrub species richness of a moderate to high cover (Tokushima et al. 2008a; OEH 2013b). Jarman & Green (2000) found an apparent preference for high understorey density (31 cm - 50 cm above the ground) and a lack of records when the shrub density was too high at upper levels. The Pilliga Mouse has also been associated with recently burnt moist gullies, areas dominated by *Melaleuca uncinata* (Broombush), areas containing an understorey of *Acacia burrowii* (Burrow's wattle) with a *Corymbia trachyphloia* (Brown Bloodwood) overstorey (Paull 2009) and in open areas on deep sand with almost no understorey and sparse leaf litter (NPWS 2002). There is potential for all vegetation connecting to primary habitat in the Pilliga to be used as dispersal habitat by the Pilliga Mouse.

2.2 Data sets

Schlencker Mapping undertook data acquisition using Airborne Laser Scanning techniques to gather Light Detection and Ranging (LiDAR) data for an area of approximately 893 km^2 in the vicinity of the study area (**Figure 2**). The capture was undertaken between December 20 and 22, 2010. Data was provided on a square 1 km by 1 km tile grid. Schlencker Mapping also developed a vegetation Canopy Height Model based on the Light Detection and Ranging information captured (Schlencker Mapping 2010).

RPS Group (2013) undertook a second round of data acquisition using Airborne Laser Scanning techniques to gather Light Detection and Ranging data for an area of approximately 95,077 ha across the study area.

Canopy Height Model data was used to identify areas of low dense shrub cover (**Figure 3**). The Canopy Height Model was classified into 5 height range classes that were assigned a red to green colour transition. Areas with taller canopy heights were assigned to the green spectrum, while low open areas were assigned to the red spectrum.

As such, most areas of potential Pilliga Mouse habitat (i.e. areas with a dense low shrub cover and open canopy) were predominantly red in the Canopy Height Model (**Figure 3**). High resolution geo-referenced aerial imagery was used to validate the Canopy Height Model assessment.

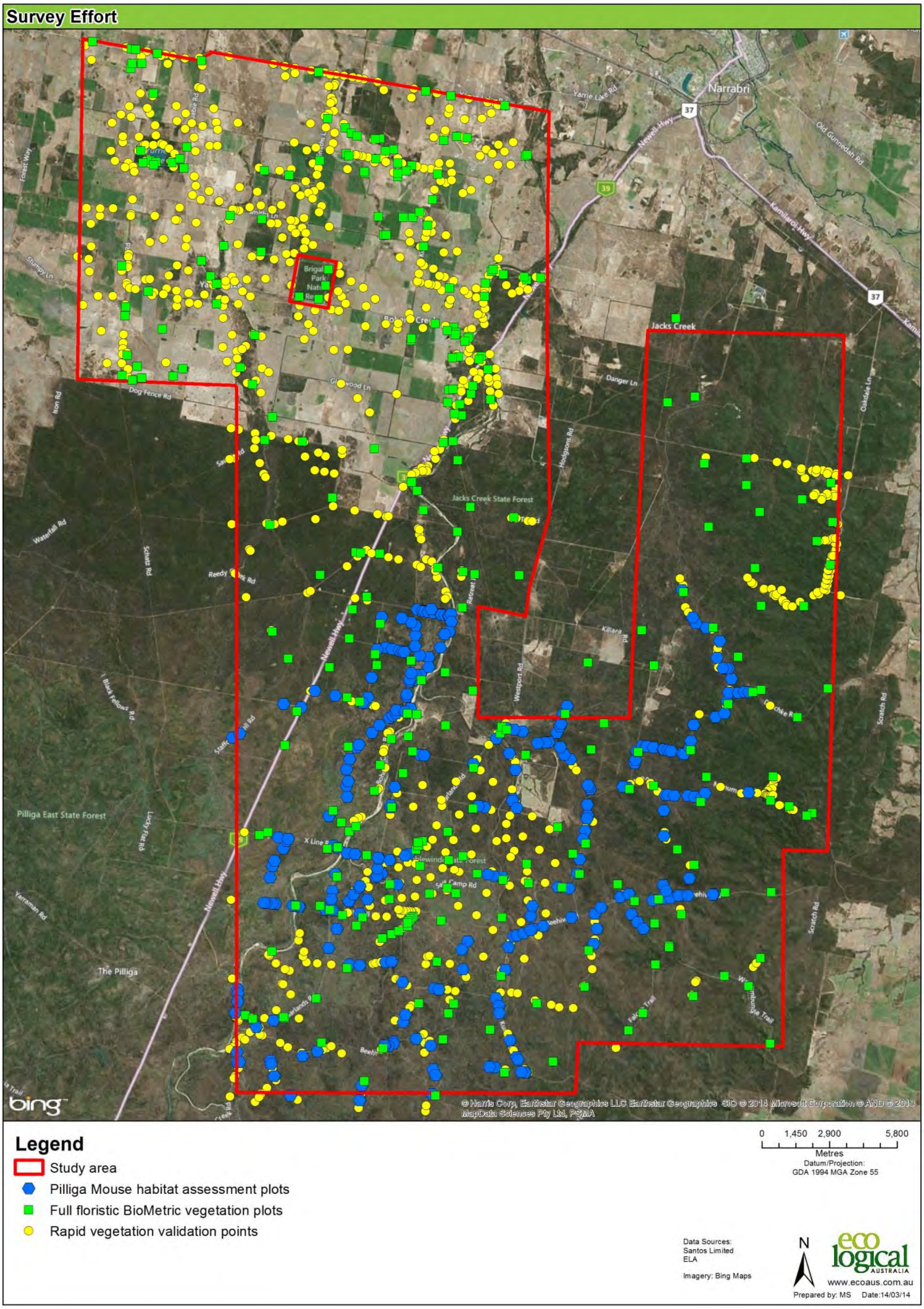

Figure 2: Survey effort

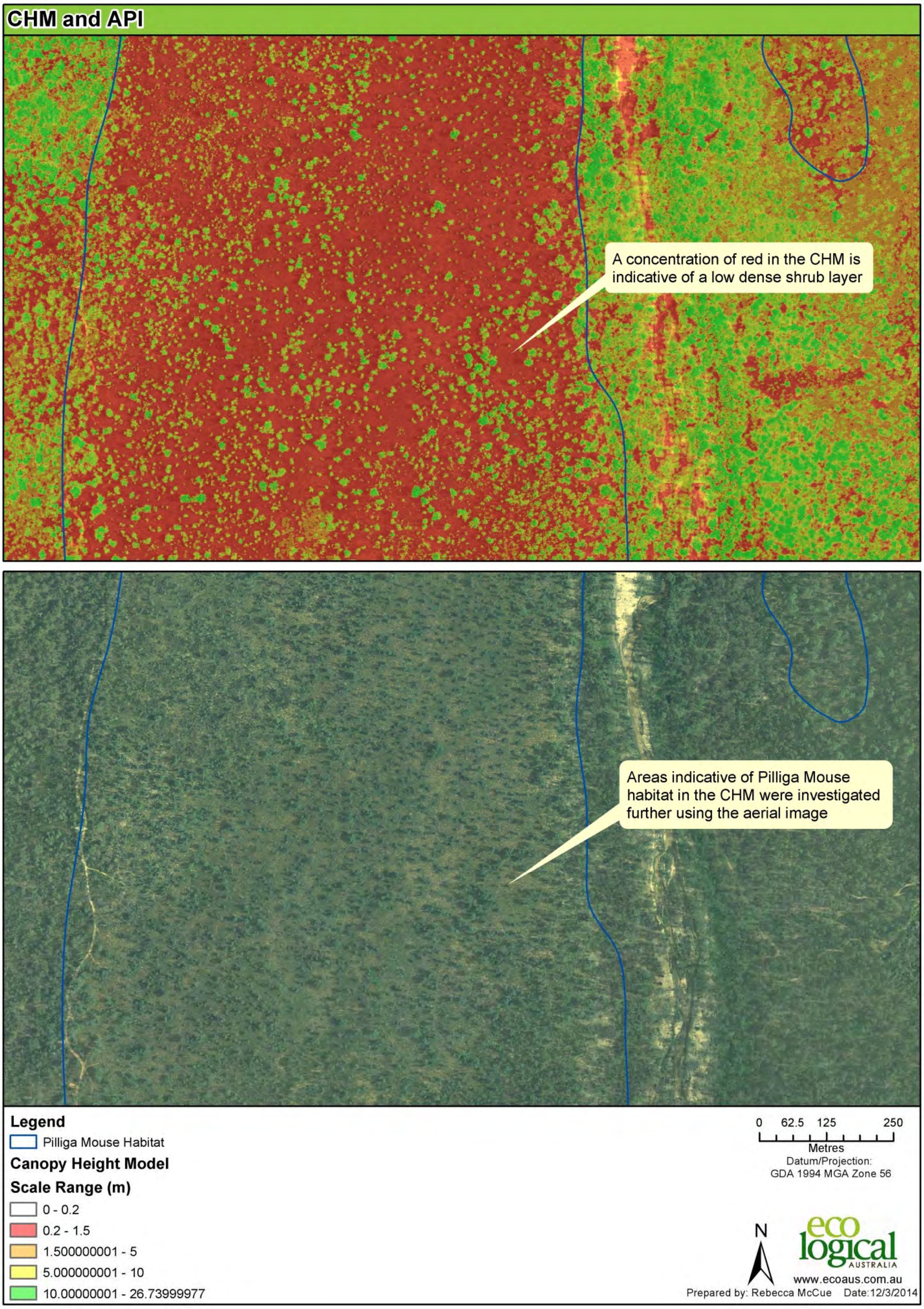

Figure 3: Canopy Height Model (CHM) and Aerial Photograph Interpretation (API)

2.3 Initial Pilliga Mouse habitat model

The Canopy Height Model was overlayed on the aerial imagery in the Geographic Information System and potential habitat was mapped at a scale of 1:20,000. Potential habitat was initially classified into 5 categories, including:

- CAT 1 – Dense Heath
- CAT 2 – Open Heathy Woodland
- CAT 3 – Open Woodland
- CAT 4 – Disturbed/Riparian – Requires investigation
- CAT 5 – Dense Heath >2 m.

Categories 1 and 2 represented areas identified in the Canopy Height Model as low dense heath and were considered areas most likely to be potential primary Pilliga Mouse habitat. Categories 3 to 5 were identified as potential Pilliga Mouse habitat that required field validation to determine suitability.

A total of 410 unique polygons (patches of potential habitat) were mapped during the development of the initial Pilliga Mouse habitat model.

2.4 Field validation

The field validation assessment was undertaken by Senior Ecologist Martin Sullivan and Ecologist Rebecca McCue from the 15 April - 19 April 2013.

Potential habitat identified in the initial habitat modelling was validated in the field utilising field Personal Digital Assistants loaded with ArcPad software and relevant Geographic Information System datasets. This involved driving on established forestry roads and trails within the study area. The start and end of habitat was recorded, and for each area confirmed or identified as potential habitat, a rapid site assessment was undertaken.

Data recorded in the rapid site assessment included: Plant Community Types of the NSW Vegetation Classification and Assessment (Allen et al. 2010), soil texture and colour, dominant canopy species, dominant midstorey species, dominant groundcovers, low shrub cover, presence/absence and size of burrows, as well as additional site notes (e.g. fire history, midstorey density and composition, etc.). A photo of each habitat patch was also captured to assist with the habitat classification.

A total of 77 rapid assessments were undertaken during the field validation survey.

2.5 Revised Pilliga Mouse habitat model

Data collected in the field was uploaded into the Geographic Information System. In order to accurately delineate areas of habitat a number of resources were used, including the rapid site assessments, the start/end habitat points, existing vegetation mapping (ELA and Forests NSW), and the draft Pilliga Mouse habitat model, which were overlayed on the Canopy Height Model and aerial images. The Canopy Height Model was also used to identify areas of habitat that were inaccessible during the field validation survey.

The assessment was generally undertaken at a finer scale of 1:15,000; although areas that were identified as potential Pilliga Mouse habitat either during the field validation survey or using the Canopy Height Model only were inspected carefully at a finer scale, using both the Canopy Height Model and aerial images.

Areas mapped were categorised as either primary (Category 1) or secondary (Category 2) habitat. Primary habitat is predicted to be inhabited more permanently by the Pilliga Mouse, while secondary habitat is expected to be inhabited less readily, after fire or in successful breeding years. Secondary habitat is generally habitat that is long unburnt and is either dominated by *Callitris endlicheri* (Black Cypress Pine) or *Callitris glaucophylla* (White Cypress Pine) in the midstorey; the heath is less dense or very tall; or it is dominated by *Acacia triptera* (Spur-wing Wattle) or *Melaleuca uncinata* (Broombrush) in the shrub layer.

Primary habitat was generally attributed when the Canopy Height Model and the aerial image indicated a dense shrub cover, the field validation points confirmed a dense low shrub cover (>30%) less than 1 m in height, a sandy soil type was recorded, and when the canopy was typically dominated by *Angophora floribunda* (Rough-barked Apple), *Corymbia trachyphloia* (White Bloodwood), *Eucalyptus chloroclada* (Dirty Gum) and *Eucalyptus fibrosa* (Red Ironbark), although a number of other canopy species were also present as subdominants. Primary habitat was mapped independently to midstorey floristic association and therefore the wider range of floristic associations suggested by Milledge (2012) is covered in the modelling.

Secondary habitat was generally attributed when the Canopy Height Model and aerial image indicated a moderate to dense shrub cover, the field validation points indicated a shrub cover of >20%, a sandy to sandy loam soil type was recorded, and where the vegetation was comprised of a mature woodland (i.e. a long time since fire) and/or had a moderate to dense midstorey, generally dominated by *Callitris endlicheri* and *C. glaucophylla.*

These areas provide a range of support values to primary habitat including increasing patch size, buffering from edge effects and providing corridor connections. Secondary habitat may also include small patches of primary habitat too small to map at the mapping scale (1:15,000). Additionally, secondary habitat would in most cases become primary habitat following a bushfire or other disturbance (i.e. clearing, thinning or canopy removal) which stimulates the growth of a dense shrubby layer. It was therefore considered important to identify these areas as they may become important in a relatively short period of time (e.g. after a summer bushfire).

Areas of potential habitat, both primary and secondary that were intersected during the field validation survey were given a score of 1 (validated). Areas of potential habitat that were mapped based purely on Canopy Height Model and Aerial Photograph Interpretation were given a score of 2 (not validated). A large portion of the areas mapped as category 2 were in the vicinity of habitat mapped at an accuracy of 1, and where appropriate were assigned the same attributes.

Potential Pilliga Mouse habitat in the forested areas in the north east, east and southeast of the study area were identified primarily based on Canopy Height Model. Supplementary data used to inform the assessment included Pilliga Mouse observational records and a number of rapid vegetation validation points undertaken as part of the developed of a vegetation map for the study area (ELA 2015). The final Pilliga Mouse habitat model was intersected with the vegetation mapping for the study area (ELA 2015) in order to more accurately assign Plant Community Types.

3 Results

A total of 1,391 unique polygons (23,204 ha), were mapped to produce the final Pilliga Mouse habitat model: 397 of these were classified as primary habitat (8,595 ha or 9.0% of the study area) while the remainder were classified as secondary habitat (14,609 ha or 15.4% of the study area) (**Figure 4**). Mapped primary habitat is connected within the study area by areas of secondary habitat.

Primary habitat is generally located on deep alluvial sand on the floodplains of major creeks or on deep sand derived from sandstone which influence plant community floristics and structure which suit the Pilliga Mouse. Secondary habitat occurs on similar soil landscapes, however it is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years.

No Pilliga Mouse habitat was mapped in the north-western section of the study area (within the Pilliga Forest) or in areas to the north of the Pilliga Forest. These areas occur on finer-grained sediments which are unlikely to support potential habitat for the Pilliga Mouse.

Primary habitat was most commonly mapped within the following Plant Community Types (Allen et al. 2010):

- ID40X: White Bloodwood –Dirty Gum –Rough Barked Apple –Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests
- ID405: White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions
- ID 404: Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests

Additional Plant Community Types in which primary habitat was mapped included:

- ID401: Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region
- ID408: Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region.
- ID406: White Bloodwood –Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests
- ID379: Inland Scribbly Gum - White Bloodwood – Red Stringybark – Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion
- ID398: 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 BBS Bioregion
- ID399: Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion

Secondary habitat was recorded in a range of Plant Community Types. Secondary primarily comprised of Plant Community Types classed as primary habitat, and also included:

- ID141: Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion
- ID425: Spur-wing Wattle heath on sandstone substrates in the Goonoo – Pilliga forests Brigalow Belt South Bioregion
- ID88: Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion

Plant Community Types ID88 and ID398 that were mapped in the Pilliga Mouse habitat model typically do not occur on suitable soils nor have a suitable low shrub diversity or density to be considered as potential Pilliga Mouse habitat (see **Section 2.1**). These communities predominantly occur on sandy loam based soils and have a sparse low shrub layer (Benson 2006). These areas were mapped adjacent to habitat that is more typical Pilliga Mouse habitat and are likely to be transitional areas between these communities. For instance, in cases where the Canopy Height Model displayed a low dense shrub layer for plant communities ID398 and ID88 in areas adjacent to the more suitable Pilliga Mouse habitat, they were mapped as secondary Pilliga Mouse habitat. Aerial Photograph Interpretation was also used to help inform the assessment of these areas.

Areas in the northeast, east and southeast of the study area were not ground-truthed as part of this assessment and therefore the confidence in the accuracy of the Pilliga Mouse habitat mapping in this region is reduced. Areas in the Canopy Height Model that appeared to have a moderate to dense low shrub layer, with or without a moderate midstorey or canopy layer, were mapped as potential Pilliga Mouse habitat based on the precautionary principle. This primarily included Plant Community Types ID404, ID406 as well as ID398.

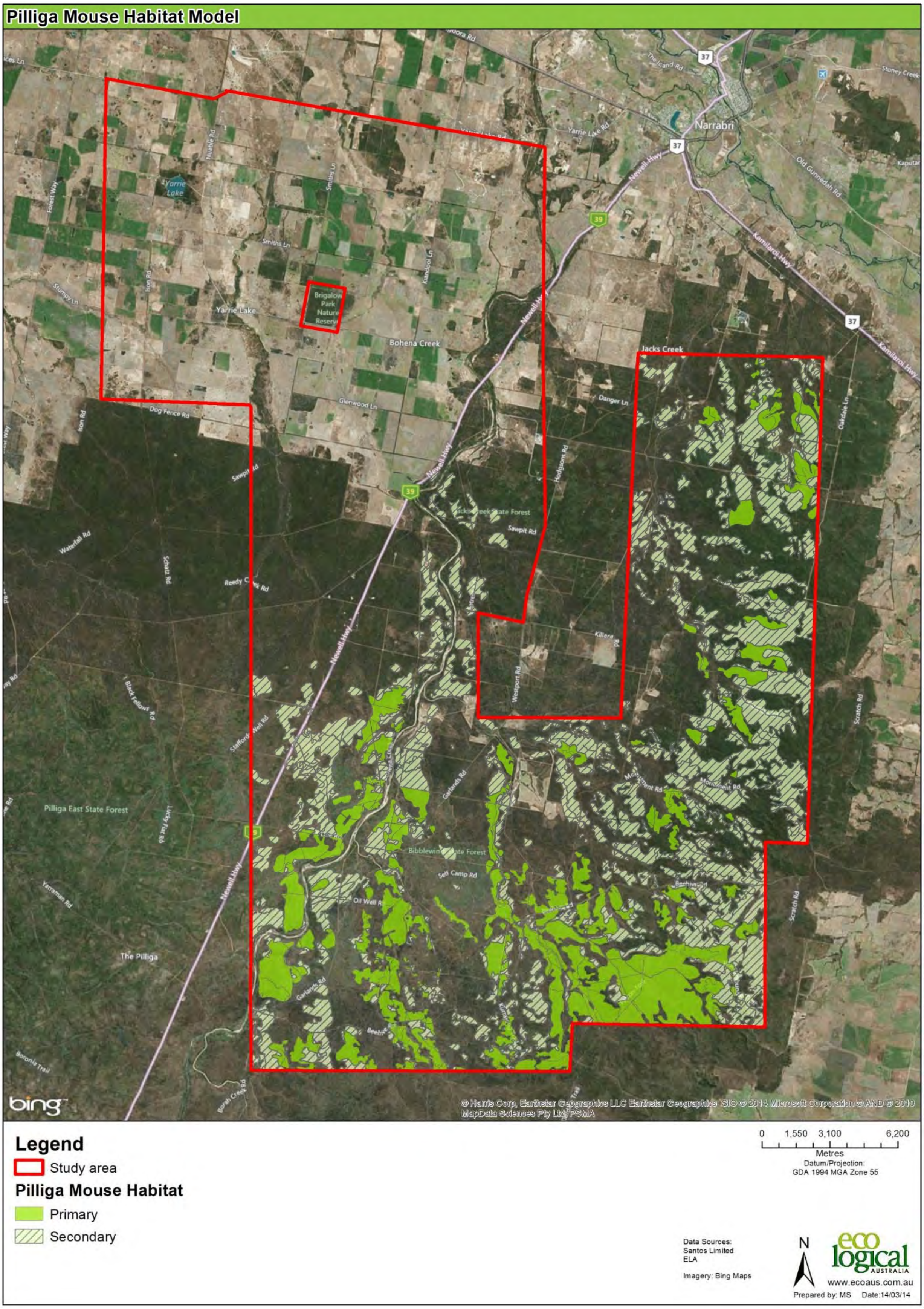

Figure 4: Final Pilliga Mouse Habitat Model

4 Use and interpretation

The Pilliga Mouse habitat model was developed to locate areas of potential primary and secondary Pilliga Mouse habitat to provide a greater understanding of the potential distribution of Pilliga Mouse habitat and assist in minimising the impacts of natural gas development on this species.

By incorporating the habitat model into the Proponents' Geographic Information System, as well as updating the Ecological Sensitivity Analysis, this model can be utilised to minimise the impacts to the Pilliga Mouse. Primary Pilliga Mouse habitat is considered more likely to be inhabited by the Pilliga Mouse on a more permanent basis, while the secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years. Secondary should be allocated a higher weighting in the Ecological Sensitivity Analysis (than non-potential Pilliga Mouse habitat) as it provides a buffer to and provides connections between primary habitat. There is potential for all remaining vegetation connecting to primary and secondary habitat to be used as dispersal habitat by the Pilliga Mouse.

A combination of Canopy Height Model, aerial photographs, field validation, rapid site assessments, previous vegetation mapping, site photographs and previous Pilliga Mouse records have been utilised to model Pilliga Mouse habitat as accurately as possible. However, there were a number limitations that may hinder the accuracy and use of the habitat model, including:

- Vehicle access was restricted to access roads and trails, with large areas of vegetation mapped entirely via the Canopy Height Model and Aerial Photograph Interpretation. On ground survey is recommended in these areas to validate Pilliga Mouse habitat if infrastructure is to be located in these areas.
- Areas of secondary Pilliga Mouse habitat that were long unburnt often had dense Cypress Pine growth. Areas of secondary Pilliga Mouse habitat were potentially discounted in areas not visited in the field validation survey as these areas are not clearly obvious in the Canopy Height Model.
- Areas of secondary and/or primary Pilliga Mouse habitat in the northeast, east and southeast of the study area may have been discounted in areas with a dense midstorey of typically *Acacia* species as these areas are also not obvious in the Canopy Height Model.
- All vegetation within the study area (within the Pilliga Forest) is considered to be dispersal habitat and thus Pilliga Mouse habitat is not limited to the areas included in the Pilliga Mouse habitat model.
- Survey effort was reduced in the northeast, east and southeast of the study area and therefore the precautionary principle has been applied when mapping this area. All vegetated areas in this region that appeared to have a moderate to dense low shrub layer in the Canopy Height Model were mapped, including areas with a moderate canopy cover. This included a number of areas mapped as Plant Community Types that do not typically meet the criteria for Pilliga Mouse habitat.

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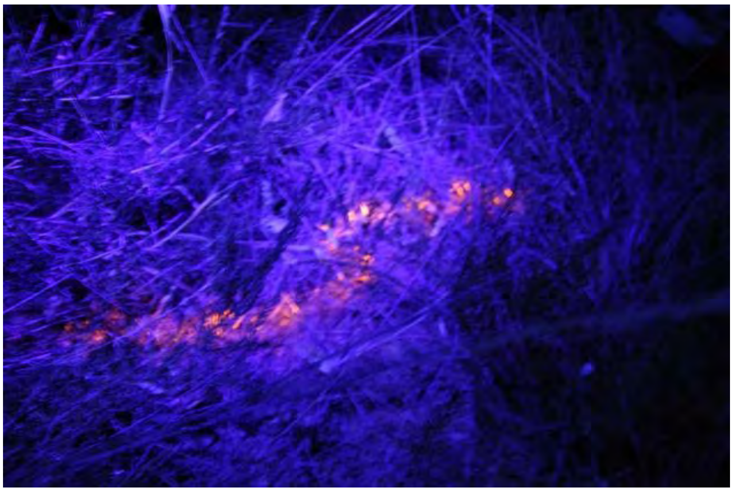
F6: Pilliga Mouse survey technical report

Narrabri Gas Project

Targeted Pilliga Mouse Survey

Prepared for
Santos NSW (Eastern) Pty Ltd

October 2015



This report should be cited as 'Eco Logical Australia 2015. *Narrabri Gas Project – Targeted Pilliga Mouse Survey*. Prepared for Santos NSW (Eastern) Pty Ltd.'

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Abbreviations

Abbreviation	Description
BoM	Bureau of Meteorology
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
LiDAR	Light Detection and Ranging
TSC Act	NSW *Threatened Species Conservation Act 1995*

Executive summary

Eco Logical Australia was engaged by the Proponent to undertake targeted *Pseudomys pilligaensis* (Pilliga Mouse) surveys for the Narrabri Gas Project which covers approximately 95,000 hectares in the northeast Pilliga Forest (the study area). The results of these surveys informed the Pilliga Mouse habitat model which forms part of the base data to be assessed in the ecological assessment for the Environmental Impact Statement for the Narrabri Gas Project.

The Pilliga Mouse is a small native murid rodent, restricted to an isolated area of low-nutrient deep sand which has long been recognised as supporting distinctive vegetation. Targeted surveys were undertaken in primary and secondary habitat during autumn and spring 2013 to investigate the distribution, abundance and habitat preferences of this species in the study area.

It is important to note that the Pilliga Mouse is now considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed and Ford 2007; Ford 2008, as cited in SEWPaC 2012). DNA analysis undertaken as part of this project supports previous studies which have shown there is no unique taxon corresponding to the Pilliga Mouse (Ford 2003). A review of the status of this species is required.

Surveys methods and techniques were developed following literature review and consultation with species experts. Surveys included Elliot A and E trapping, pitfall trapping, hair tubes and fluoro tracking to identify locations of burrows.

The Pilliga Mouse was recorded in three locations within the study area and in two locations outside of the study area, in areas considered to be primary and secondary habitat. Relevant habitat characteristics included heathy woodland with a low, diverse and relatively dense shrub layer, a diverse ground layer and sandy soils which are conducive to burrowing. One burrow was found in primary habitat during fluoro tracking.

Survey techniques and conditions were considered conducive to capturing this species but a relatively low capture rate suggests that this species was not in irruption phase at the time of the autumn surveys in 2013. This is supported by the low level of spring rainfall during 2012.

Based on the results of surveys and habitat modelling, the distribution of the Pilliga Mouse in the study area is likely to be confined to primary and secondary habitat in the south and east of the study area. These habitats included patches of woodland along Bohena Creek, Bibblewindi Creek and Cowallah Creek and a mosaic of primary and secondary habitats in the south and east of the study area. The abundance of Pilliga Mouse in these areas is likely to fluctuate depending on seasonal conditions and fire history.

Based on existing population size estimates the study area has the potential to carry up to 45,655 individuals in primary habitat alone (low density at up to 5 individuals per hectare). However it should be noted that not all primary habitat patches have been surveyed, nor will the Pilliga Mouse occur in all patches of primary habitat at all times. Potential Pilliga Mouse populations in the study area during irruption phases are expected to be an order of magnitude higher.

The Pilliga Mouse is not restricted to the study area, with a large number of existing records to the south, south-west and west of the study area within the Pilliga region. Individuals on the edges of the study area are likely to interact with other individuals by moving across these habitats outside of the study area, especially in irruption phases. The habitats in the study area form part of a wider area of habitat for the Pilliga Mouse that occurs within the Pilliga region.

1 Introduction

1.1 Background

Pseudomys pilligaensis (Pilliga Mouse) is a small native Australian murid rodent that was first described in 1981 (OEH 2014). This species is listed as Vulnerable under both the NSW *Threatened Species Conservation Act 1995* (TSC Act) and the federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and has been previously recorded within and adjacent to the study area of the Narrabri Gas Project.

This species has a current known distribution that is centred on the Pilliga region of New South Wales (NSW) with a few records from Binnaway Nature Reserve (approximately 30 km south-east of Coonabarabran) (OEH 2013, NPWS 2002, Jarman & Green 2000) and the Warrumbungles, where it was trapped in January 2013 after a major wildfire (OEH 2014). Records within and adjacent to the study area are shown in **Figure 2**.

It is important to note that the Pilliga Mouse is now considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed and Ford 2007; Ford 2008, as cited in SEWPaC 2012). Records from Bebo State Forest (approximately 230 km north-east of Narrabri) thought to be Pilliga Mouse have been subsequently determined as Delicate Mouse. It is important to note that this taxonomic change has not yet been formally recognised under State or Federal legislation; hence this report considers the Pilliga Mouse as currently listed.

Habitat requirements for the Pilliga Mouse are not fully understood but it is thought that there are primary habitats that play important roles as refuge habitats in times of population contraction and a wider range of habitats that are used during population irruptions when conditions are more favourable (Tokushima et al. 2008). Primary Pilliga Mouse habitat is considered more likely to be inhabited by the Pilliga Mouse on a more permanent basis, while the secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years.

Population size has been estimated to be approximately 50,000 to 100,000 during irruptive periods (Paull and Milledge 2011). Peak density has been calculated at 15 to 90 mice per hectare, in comparison to low density which has been calculated at below 5 mice per hectare (Tokushima et al. 2008).

1.2 Purpose of report

The purpose of this report is to present and discuss the results of Pilliga Mouse surveys that were undertaken within the study area during autumn and spring 2013. The abundance, distribution and habitat preferences of the Pilliga Mouse in and adjacent to the study area are also discussed with reference to the Pilliga Mouse habitat modelling (ELA 2015).

2 Methods

2.1 Introduction

The purpose of the surveys was to gain information about the distribution, abundance and habitat preferences of the Pilliga Mouse within the study area. Site locations, survey timing and survey techniques were selected following a review of relevant literature, database searches, habitat modelling (ELA 2015) and consultation with Dr Hideyuki Tokushima.

Autumn surveys consisted of targeted surveys (Elliot trapping, pitfall trapping and hair tubes) in areas that were modelled as primary or secondary habitat for the Pilliga Mouse (ELA 2015). Spring surveys did not specifically target modelled Pilliga Mouse habitat, but were part of a more general fauna survey involving the use of the same targeted survey techniques at multi-fauna sites.

Survey sites are shown in **Figure 1**.

2.2 Database and literature review

The Atlas of NSW Wildlife (OEH 2013) was searched for records of the Pilliga Mouse within a 50 km radius around the centre of the study area. To ensure that all known records of this species in the study area were identified data from previous fauna surveys (which may or may not be included in the Atlas of NSW Wildlife search results) were also obtained and mapped.

Literature reviewed included the following State and Federal profiles and all technical papers listed in the **References** section of this report:

- Commonwealth *EPBC Act* SPRAT profile http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=99
- NSW Environment and Heritage online profile http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10690

2.3 Habitat modelling

Habitat for the Pilliga Mouse is difficult to map on a landscape and vegetation community scale due to its small home range (Tokushima and Jarman 2008) and micro-habitat requirements. The Pilliga Mouse has been previously recorded within and around the study area in the following Plant Community Types (Kendall & Kendall 2005 & 2009, Milledge 2012, RPS 2013, Tokushima et al. 2008; Paull 2009; Paull 2002; Jefferys and Fox 2001):

- Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion
- Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern BBS Bioeregion
- Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion
- 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 BBS Bioregion
- Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests
- Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region

- Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion
- White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests
- White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions
- White Bloodwood –Dirty Gum–Rough Barked Apple –Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests

To identify areas of primary and secondary Pilliga Mouse habitat within the study area, a desktop assessment followed by a field habitat validation assessment was undertaken. Potential Pilliga Mouse habitat was initially identified using vegetation Canopy Height Model in conjunction with Aerial Photograph Interpretation in a Geographic Information System. Areas within the Canopy Height Model indicative of Pilliga Mouse habitat (i.e. areas with a dense low shrub cover) were mapped and flagged for further field validation.

A field validation survey assessed the accuracy of the initial habitat modelling as well as mapping new areas of habitat not originally identified. Rapid field assessments were taken at each site considered to constitute potential Pilliga Mouse habitat with vegetation type, dominant species, shrub cover and soil type recorded. Based on the field assessment, the habitat modelling was further refined.

The Pilliga Mouse habitat model was developed to provide a greater understanding of the potential distribution of Pilliga Mouse habitat within the study area. Habitat was classified into primary and secondary habitat. Primary habitat is predicted to be inhabited more permanently by the Pilliga Mouse, while secondary habitat is expected to be inhabited less readily, after fire or in successful breeding years. Secondary habitat is generally habitat that is long unburnt and is either dominated by *Callitris endlicheri* (Black Cypress Pine) or *Callitris glaucophylla* (White Cypress Pine) in the midstorey; the heath is less dense or very tall; or it is dominated by *Acacia triptera* (Spur-wing Wattle) or *Melaleuca uncinata* (Broombrush) in the shrub layer.

More detail on the Pilliga Mouse habitat modelling can be found in *Pilliga Mouse Habitat Assessment* report (ELA 2015).

2.4 Survey site selection and timing

2.4.1 Autumn 2013

Surveys during autumn were undertaken over a four week period between 5 May and 1 June using a range of survey techniques. This survey period was chosen as it closely follows the breeding season maximising the chances of trapping the Pilliga Mouse during peak population densities (Tokushima et al. 2008).

Sites were selected to include replicate sampling of a range of vegetation structures, shrub densities and soil substrates in primary and secondary habitat identified in the habitat modelling (**Appendix B**; **Figure 2**).

Sites PM01, PM02, PM05, PM09, PM10, PM12, HT24 and HT26 had been burnt approximately five years prior to the survey and the remaining sites were long unburnt.

Elliot trapping and pitfall trapping were undertaken during Week 1 and Week 4 only, while hair tubes were set out during Week 1 and collected during Week 4. Trapping at most sites was for five nights. However, some sites were closed one night earlier for ethical reasons. In addition, on the second day of Week 2 the Elliot traps in PM10 were moved approximately 20 metres from an area of dense *Acacia caroleae* to an area with a lower density of *A. caroleae* and a higher diversity of other low shrubs. Hair tubes were left out for between 19 to 21 nights.

2.4.2 Spring 2013

Spring survey sites (multi-fauna trapping sites) were not deliberately located in modelled Pilliga Mouse habitat because these surveys consisted of more general fauna surveys in the study area. Nonetheless, spring surveys included the use of some of the targeted Pilliga Mouse survey techniques and so are included in this report.

Surveys during spring were undertaken over a four week period between 14 October and 6 November 2013 and include Elliot trapping, pitfall trapping and hair tubes (**Appendix B**). The number of site, traps and timing of surveys is provided in **Appendix A** and survey sites are shown in **Figure 1**.

Elliot trapping and pitfall trapping were undertaken during Week 1 and Week 4 only, while hair tubes were set out during Week 1 and collected during Week 4. Trapping at most sites was over four consecutive nights. However, some sites were closed one night earlier for ethical reasons. Hair tubes were left out for between 20 to 22 nights.

Only site MFb06 had been burnt approximately five years prior to the survey and the remaining sites were long unburnt

2.5 Specialist consultation

The survey design and methodology for the autumn survey was prepared with consultation from Dr Hideyuki Tokushima (Pilliga Mouse expert) who considered that the trapping design and survey procedures were well considered and appropriate for detection of the species. Comments by Dr Tokushima are summarised as follows:

- *Fire age of sites*. Selection of sites in respect of fire is adequate, since some studies show that it is more important to consider vegetation density or other habitat variables other than time since fire.
- *Diversity of shrubs*. Shrub diversity may affect habitat for the Pilliga Mouse. High shrub diversity seems to provide continuous (over time) habitat but low shrub diversity seems to only provide habitat in times of population irruption. Dr Tokushima suggested that sampling sites that have low diversity can help confirm to whether shrub diversity affects habitat use in this way.
- *Grid trapping design*. While a grid design of 0.25 hectares is an effective trapping area, it may capture only a few individuals since in most cases in studies undertaken by Dr Tokushima population density (in times outside of irruption) was less than five individuals per hectare. This design should be reviewed following the first survey to determine whether it is worth expanding the grid size by increasing the distance between traps.
- *Bait*. Dr Tokushima considers that small changes to rolled oats and peanut butter bait (for example, adding honey) are not likely to overly affect trap capture rate.
- *Scent*. Dr Tokushima caught Pilliga Mouse in the same traps following capture of *Mus musculus* (House Mice) and *Antechinus* spp. and so does not consider that scent from other animals in traps would have a meaningful effect on the ability to capture the Pilliga Mouse.
- *Checking of traps*. Checking once per day would be adequate and pitfalls should have drainage and be checked more often during rain.
- *Hair tubes*. Dr Tokushima did not find that hair tubes resulted in many detections of the Pilliga Mouse when compared with Elliot trapping.

- *Handling of mice.* The use of plastic bags and handling of the Pilliga Mouse by Dr Tokushima was described. Dr Tokushima advised that handling of the tail should be avoided since the skin can be accidentally stripped away.

Specialist information provided by Dr Tokushima was taken into account when designing targeted surveys, when handling the captured Pilliga Mouse and in the discussion of the results of these surveys.

Dr Fred Ford (recognised expert on molecular determination of *Pseudomys* species in Australia) was consulted regarding the status of the Pilliga Mouse, appropriate methods for DNA analysis and interpretation of results. Dr Ford also provided expert advice to the Australian Centre for Wildlife Genomics at the Australian Museum who completed the DNA analyses for this project.

2.6 Survey techniques

Targeted Pilliga Mouse survey techniques were chosen following a review of literature and discussion with Dr Tokushima. Surveys included Elliot traps, pitfalls and hair tubes. Fluoro marking and DNA sampling methods are also described in this section.

2.6.1 Elliot trapping

At sites using Elliot trapping, 36 traps were placed in a six by six grid spaced approximately 10 metres apart. Autumn grids included 26 standard A-size Elliots and ten smaller E-size Elliots and spring grids included 28 standard A-size Elliots and eight smaller E-size Elliots. Traps were baited with rolled oats, peanut butter and honey (a trace of truffle oil was added for the spring surveys) and set for four or five nights. Prior to setting the traps the sensitivity of the trigger was adjusted so that it would release the door with very light weights (approximately 8 g).

During autumn surveys small squares of wool and/or leaf litter was placed inside the traps for insulation and litter was placed on top of the trap for insulation and heat protection. During spring surveys the Elliot traps were placed within calico bags for heat protection and wool was also placed inside for insulation and heat protection.

Traps were checked each morning over three to five mornings. Weight, head and rear pes of captured animals were measured and photos were taken. Animals captured were released on the morning of capture.

2.6.2 Pitfall trapping

In autumn pitfall trapping consisted of three small size pitfalls (PVC pipe 15 centimetres in diameter and between 30 and 50 centimetres deep) located adjacent to the Elliot trapping grid. Pitfalls had wire mesh netting at the base to facilitate drainage and stop fauna from burrowing out. Pitfall traps were spaced between 10 to 30 metres apart, and each pitfall had a five metre length of drift fence made from plastic damp course on either side. Litter and wool was placed inside the pitfalls for cover, insulation and heat protection.

Pitfalls were checked each morning over four or five mornings. Weight, head and rear pes of captured animals were measured and photos were taken. Animals captured were released on the morning of capture.

2.6.3 Hair tubes

Hair tubes consisted of PVC piping approximately 30 millimetres diameter for the autumn survey and 50 millimetres diameter for the spring survey. Double-side tape was placed on the inside top of the tube.

Hair tubes were baited with rolled oats, peanut butter and honey. Hair tubes were set out over the first week of survey and collected in the fourth week during both autumn and spring surveys.

Autumn hair tube sites consisted of 20 hair tubes. Two transects of five hair tubes were placed on opposite sides of, and perpendicular to a road. Transects were spaced approximately 10 to 20 metres from each other and hair tubes within each transect were set approximately 10 metres apart. The 20 hair tubes that were set out at the Broombush sites (PM01and PM02) were placed next to 20 of the Elliot traps in the Elliot trapping grid.

Spring hair tube sites consisted of ten hair tubes at each site, placed every 100 m on the ground in a transect parallel to a road. All hair tubes were at least 20 m away from the road edge. The exception to this set up is at site HT31 where the habitat patch was not large enough along the roadside, so transects were set up running perpendicular to the road. The site consisted of two transects, approximately 40 meters apart. Each transect consisted of 10 small hair tubes each, approximately 10 meters apart.

2.6.4 Mark/recapture and DNA analysis

Once a Pilliga Mouse was captured, a permanent 1 mm ear notch was collected from each individual by suitably qualified and competent staff member. The removal of ear notches was undertaken in accordance with the standard operating procedures outlined in the DEC (2009) *Permanent marking of mammals using ear notching.*

The removal of ear notches from captured mammals was undertaken in the presence of two ecologists. One ecologist (whilst wearing sterile gloves) was responsible for calmly handling the captured animal, the use of sterile 1 mm ear notching scissors to remove the ear notch and the placement of the ear notches into an individual 1.5 ml Eppendorf Tube containing dimehtylsulfoxide (DMSO). The other ecologist was responsible for note taking and record keeping, non-sterile equipment and the disposal of used equipment.

The placement of the ear notch differed between individuals and, therefore, provided a unique and identifiable number/mark (DEC 2009). Following the removal of the notch, a gauze swab or tissue containing Betadine was applied to the notched area to prevent infection. If the notch bled, light pressure was exerted over the area while using clean dry gauze until the bleeding stoped. Each tissue sample was returned to the Australian Museum for DNA analysis. All equipment was sterilised (using Ethanol) between individuals.

If sufficient individuals were trapped and re-trapped, a capture – recapture program was proposed to be implemented using the program MARK, with the aim of estimating population density at the time of survey. However, sufficient numbers were not caught during this survey.

Three captured Pilliga Mouse at the two separate sites were marked with fluorescent powder and released in the morning of capture on separate days. Each captured Pilliga Mouse was placed into a calico capture bag and handled by an experienced and competent wildlife ecologist. Its face was covered for a short period by the capture bag, while powder is quickly, but gently, brushed into its belly hair. Once the belly hair is sufficiently coated with powder it was released at its point of capture. The point of release was marked with flagging tape allowing for the ecologist to return to the exact location once it has become dark that evening and follow the trail to measure the tracks using a UV light. During the tracking process all adjacent traps were closed.

2.7 Survey effort

Detailed survey effort for each site is shown **Appendix A**.

2.8 Weather conditions

Weather data was sourced from the Bureau of Meteorology (BoM) website and is for the Narrabri Airport weather station. Rainfall and temperature during autumn and spring surveys and rainfall data for the previous five years are provided in **Appendix C**.

Temperatures during autumn surveys were slightly lower than average while temperatures during spring surveys were slightly higher than average (calculated for the years 2001 to 2014). Rainfall during the autumn surveys was on or above average while rainfall during the spring surveys was lower than average.

Rainfall data over the previous five years shows that spring rainfall in 2012 was much lower than average, while the summer rainfall of 2011/2012 was higher than average. The year 2010 has on or above average rainfall except for in winter, in which no rain fell in July or August. The years 2008 and 2009 both received above-average rainfall in summer and variable rainfall during the rest of the months.

2.9 Survey limitations

All surveys have limitations or involve factors that must be taken into account when analysing results. These factors often involve climatic and seasonal conditions which can affect population dynamics at particular times. The surveys were timed to occur during optimal periods (post breeding in autumn and during breeding in spring); however seasonal conditions such as rainfall, fire and resource abundance may have influenced the results of the survey.

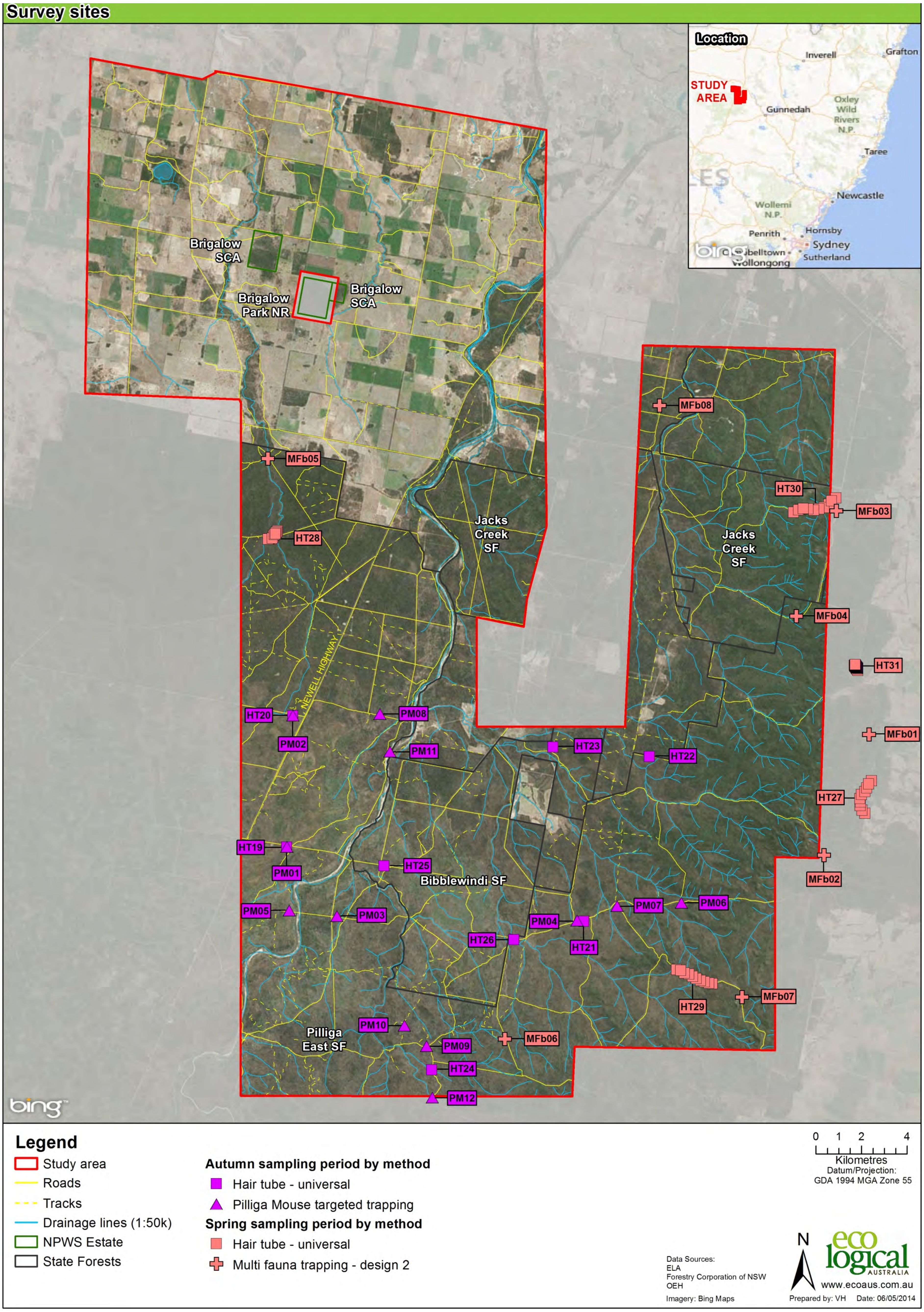

Figure 1 Survey sites

3 Results

3.1 Autumn 2013

Pilliga Mouse was detected only in Week 1 at two sites in a pitfall trap, A-size Elliot traps and E-size Elliot traps (**Figure 2**). Details of captures are presented in **Table 1**.

Table 1: Autumn Pilliga Mouse captures

Date	Site	PCT/modelled habitat	Survey technique	Sex/breeding	Weight (g)
8 May 2013	PM08	ID40X: White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests / Primary	Pitfall	Female (non-breeding)	6.2
9 May 2013	PM08	ID40X: White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests / Primary	E-size Elliot trap	Female (non-breeding)	7.25
10 May 2013	PM08	ID40X: White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests / Primary	A-size Elliot trap	Female (recapture of the same individual caught 9 May 2013)	7.25
11 May 2013	PM08	ID40X: White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests / Primary	A-size Elliot trap	Male	9.5
11 May 2013	PM05	ID40X: White Bloodwood – Dirty Gum – Rough Barked Apple heathy open woodland on deep sand in the Pilliga forests / Primary	E-size Elliot trap	Female	12

Capture rates were too low to use a mark-recapture analysis to estimate population density. However, a more general estimate of the population size can be made based on the number of captures and the size of the trapping grid.

Three individual females and one male were captured. The weights of the captured females ranged from 6.2 to 12 grams but none showed obvious signs of breeding. The weight of the male was 9.5 grams. Three of the individuals were captured at PM08. This trapping site was approximately 0.25 hectares and therefore the rough estimate of the number of individuals per hectare in this habitat is 12. One individual was captured at PM05. This trapping site was also 0.25 hectares and therefore the rough estimate of the number of individuals per hectare at PM05 is four. Limitations with estimating population sizes and densities are discussed in Section 4.2.

Vegetation at PM08 and PM05 provided similar habitat in terms of dominant canopy species, shrub cover and diversity, ground layer diversity and sandy soil substrate. PM05 has a canopy dominated by *Angophora floribunda* and *Eucalyptus chloroclada* (approximately 10% to 30% foliage projective cover). The midstorey is open and comprises juvenile eucalypts and *Acacia* spp. (approximately 1 m to 4 m height and 5% foliage projective cover). A low shrub layer (approximately 1 m height and 20% to 40% foliage projective cover) is dominated by *Calytrix tetragona, Grevillea floribunda, Bossea rhombifolia, Dodonaea* spp. and *Melichrus* sp. The groundcover is sparse (<10% foliage projective cover) with *Aristida* sp. and leaf litter.

PM08 has a canopy dominated by *E. chloroclada* (6 m to 10 m height and 10% foliage projective cover). The midstorey is open (approximately 2m height and 5% to 20% foliage projective cover) and dominated by *Dodonaea* sp. and *Acacia* spp. The low shrub layer (approximately 1m height and 50% foliage projective cover) is dominated by *Brachyloma daphnoides, Grevillea floribunda* and *Boronia* sp. The groundcover moderate (50 % foliage projective cover) but patchy and is dominated *Aristida* sp, *Digitaria* sp., *Schoenus* sp. and *Laxmannia gracilis*.

Fluoro powder was applied to the Pilliga Mouse captured at PM08 on 9 May and it was released that morning. The same evening the trail was followed to a burrow approximately 2.5 centimetres wide and 16 metres from its capture point. The burrow appeared to be deeper than 15 centimetres but did not appear to show signs of digging and could have been a disused insect or spider burrow. A photo of the burrow is shown in **Plate 1**, a Pilliga Mouse in **Plate 2** and a fluoro trail from tracking shown in **Plate 3**.

Plate 1: Pilliga Mouse burrow

Plate 2: Pilliga Mouse

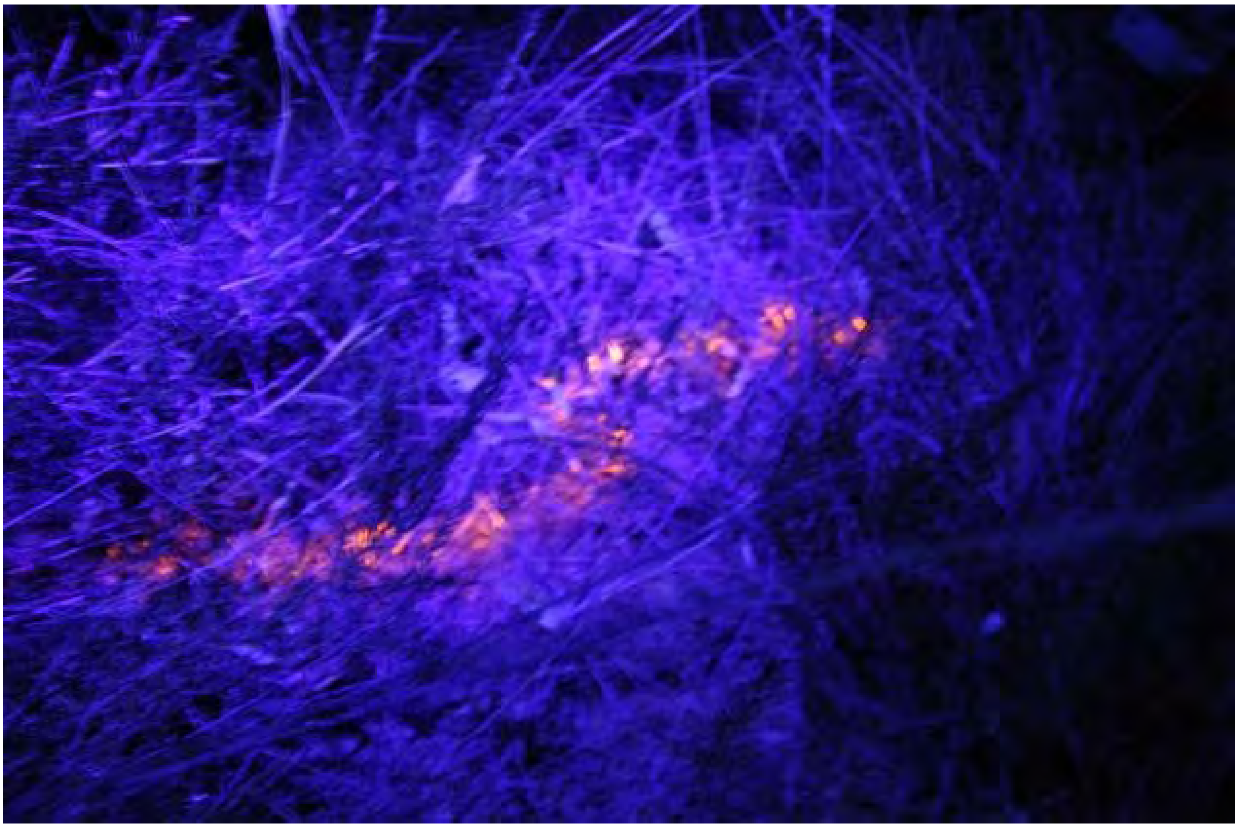

Plate 3: Fluoro trail from Pilliga Mouse tracking

3.2 Spring 2013

The Pilliga Mouse was detected at three sites in an A-size Elliot, a pitfall trap and a small hair tube. Details of captures are presented in **Table 2**.

Table 2: Spring Pilliga Mouse captures

Date	Site	PCT/modelled habitat	Survey technique	Sex/breeding	Weight (g)
15 October 2013	MFb03	ID404: Red Ironbark – White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soils in the Pilliga forests / Secondary	Pitfall	Not recorded	10
18 October 2013	MFb04	ID404: Red Ironbark – White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soils in the Pilliga forests / Secondary	A-size Elliot	Not recorded	10.5
Undefined	HT31	ID404: Red Ironbark – White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soils in the Pilliga forests / Secondary	Small hair tube	Not possible to detect	Not possible to detect

The two individuals captured during spring weighed 10 grams and 10.5 grams. Vegetation at MFb03 and MFb04 provided similar habitat in terms of shrub cover and diversity and a sandy soil substrate. Vegetation at site MFb03 consisted of *Eucalyptus fibrosa*/*Corymbia trachyphloia* woodland with an open layer of regenerating Eucalyptus to 2 m high. The understorey was mid-dense (50% foliage projective cover) up to 1 metre high and dominant species included *Calytrix tetragona and Philotheca* sp. and the ground layer was dominated by *Aristida* sp.

Vegetation at site MFb04 consisted of *E. fibrosa* open woodland with a mid-dense midstory 1-3 m high and dominated by *Pomaderris* sp. and *Bursaria spinosa*. Drainage lines contained a dense layer (80% foliage projective cover) of *Pomaderris* sp. The ground layer was mid-dense and dominated by *Gahnia aspera* and *Cymbopogon refractus*.

Site MFb04 was mapped as secondary habitat as it had a relatively dense overstorey and a mid-dense midstorey 1-3 m in height which varied from other sites characterised by a diverse low shrub layer. As stated in the habitat assessment report secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years (ELA 2015). However, this does not preclude the occurrence of Pilliga Mouse in this secondary habitat.

Vegetation at Site HT31 consisted of an open canopy layer of *E. fibrosa* and *C. trachyphloia* (less than 10% foliage projective cover) and dense midstorey (50% to 60% foliage projective cover) dominated by *Triodia mitchellii* var. *breviloba* (Buck Spinifex), *Brachyloma daphnoides, Hibbertia* sp., *Calytrix tetragona* and *Homoranthus flavescens*.

Deep sandy soil was observed at all sites where Pilliga Mouse was recorded.

3.3 DNA Analysis

Five ear notches from Pilliga Mouse captured during this study were sent to the Australian Centre for Wildlife Genomics at the Australian Museum for DNA analysis. The results of the DNA analysis are included in **Appendix E**.

Of the five samples sent for analysis, four returned mitochondrial DNA results consistent with Delicate Mouse and one was consistent with *Pseudomys novaehollandiae* (New Holland Mouse). All samples were collected from the Pilliga region (including the Australian Museum reference collection) have been assigned to Pilliga Mouse purely based on geography rather than DNA as it is currently recognised under the TSC Act and EPBC Act as vulnerable.

While some authors have described Pilliga Mouse as a ‘species’, recent molecular evidence (including the results of this study) does not support this distinction (F. Ford pers. comm, cited in Australian Museum 2013a) as the level of interspecies difference we would typically observe between distinct species is not seen (Australian Museum 2013a).

It is likely that the Pilliga Mouse population in the Pilliga region represents a population of Delicate Mouse that, in the past, has hybridised with a population of New Holland Mouse (F. Ford pers. comm, cited in Australian Museum 2013a). The results of the DNA analysis are consistent with this hypothesis with four samples being consistent with the mitochondrial DNA of Delicate Mouse and one of New Holland Mouse.

The results of this study support genetic work previously conducted by Dr Ford for his PhD thesis which found there is no taxon corresponding to Pilliga Mouse (Ford 2003). A review of the status of this species is required.

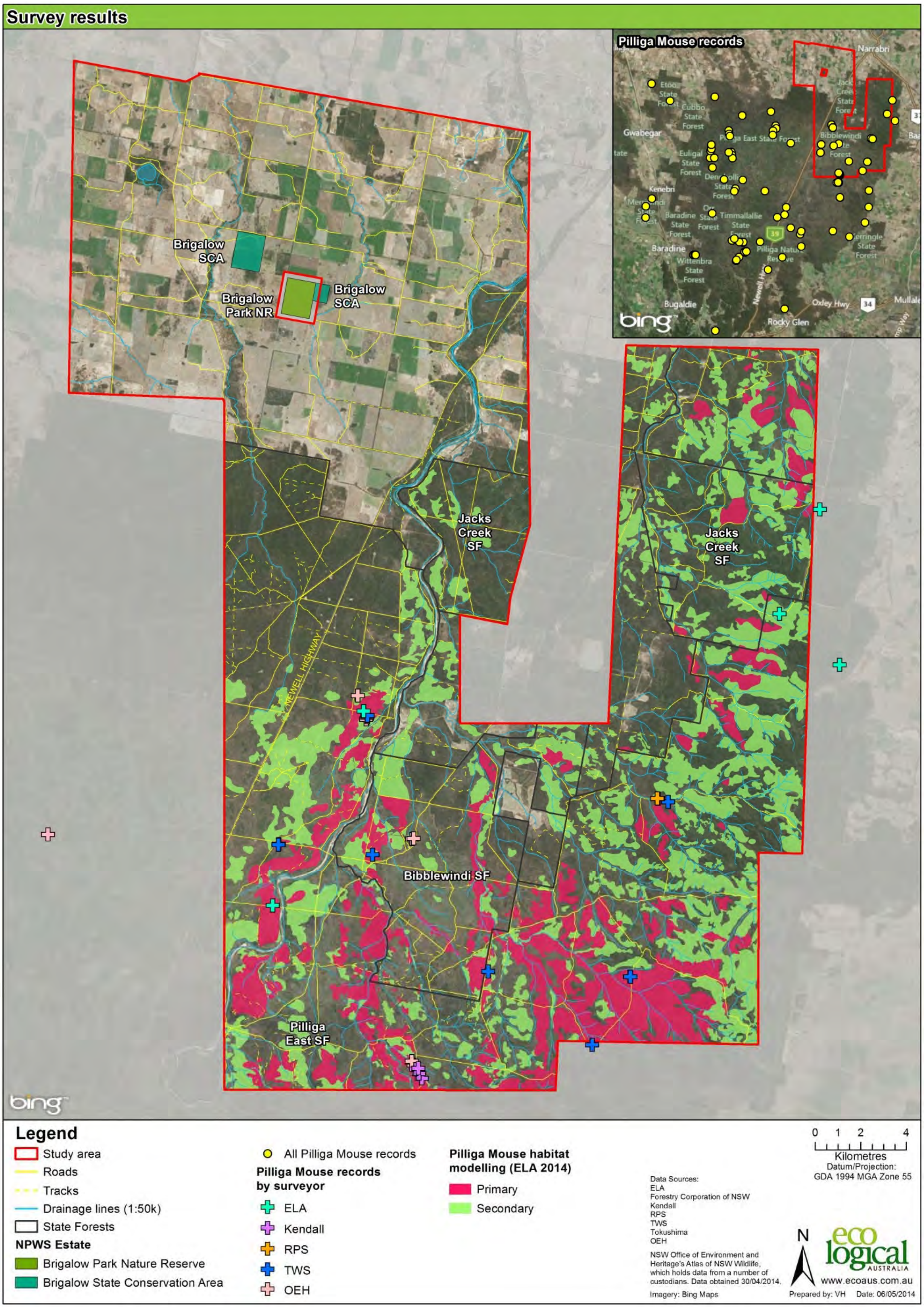

Figure 2: Survey results

4 Discussion

4.1 Habitat preferences

The Pilliga Mouse has been previously recorded in a wide range of habitat types within the Pilliga region, including forests, woodlands, heath and shrublands (see **Appendix D**). Consistent characteristics of Pilliga Mouse habitat include a high cover and diversity of the low shrubs as well as a sandy soil substrate in woodland and forest communities (Tokushima et al. 2008; OEH 2013; Paull et al. 2014).

During these targeted surveys, the Pilliga Mouse was captured or detected at five different sites using all types of targeted survey techniques. It had been previously recorded at site PM08, however, the other four sites represent new records for the study area. The closure of traps a night earlier at some sites where the Pilliga Mouse was not detected is unlikely to change the results of the survey at these sites. This is because these sites contained less suitable habitat (no low shrub layer or lack of a suitable burrowing substrate) and the presence of the Pilliga Mouse at these sites during the time of surveys (in a normal phase) was not likely.

Almost all the sites in which the Pilliga Mouse was captured or detected supported habitat features that are consistent with habitat descriptions in the literature. These features include a low, diverse shrub cover and suitable burrowing substrate (Tokushima et al. 2008, Paull 2009). Only site MFb04 contained different habitat features in the form of a high shrub layer with a high foliage projective cover. This site was mapped as secondary habitat but it should be noted that this only suggests that there is a low chance of the Pilliga Mouse being present in such habitats during normal phases. Therefore, the detection of the Pilliga Mouse at this site is still consistent with the literature and habitat modelling (ELA 2015). Other sites with suitable burrowing substrates in which no Pilliga Mouse was captured or detected had either a very low cover of shrubs or a very high cover of taller shrubs. This is also consistent with the literature on habitat preferences and habitat modelling which predicts a low chance of the Pilliga Mouse being present in these areas during normal phases.

The Pilliga Mouse was only captured or detected in sites that had a suitable burrowing substrate in the form of relatively deep sandy soil. The lack of captures at other sites that had a relatively high cover of low, diverse shrubs could be explained by the fact that the substrate at these sites was not optimal for burrowing. The soil at these other sites was clay loam, which extended to a depth of about 40 to 50 centimetres, after which the soil changed to hard clay. This substrate is not considered suitable for burrowing for the Pilliga Mouse and the Pilliga Mouse is only likely to occur in these low-suitability habitats in irruption phases.

Fire is also likely to influence the habitat preferences of the Pilliga Mouse. Paull (2009) argues that time since fire in broombush vegetation affects the cover of the lower shrub layer and that habitat for the Pilliga Mouse needs a high cover (over 50%) of the lower shrub layer. However, this is not likely to be applicable to broombush sites in this report since the lack of suitable burrowing substrate is likely to preclude the preference of the Pilliga Mouse for these sites in normal phases. Nonetheless, fire may still influence the development of a low diverse shrubby layer in other sites with suitable burrowing substrates. For example, areas mapped as secondary habitat often contained suitable burrowing substrates and a dense mid storey of *Callitris endlicheri* (Black Cypress Pine) or *Callitris glaucophylla* (White Cypress Pine) which is likely to preclude a dense low shrub layer. These areas are likely to become primary habitat following suitable fire regimes in which the *Callitris* layer is removed or reduced and a low diverse shrubby layer develops.

In summary, the results of the surveys were consistent with the habitat preferences of the Pilliga Mouse during a normal phase that is reported in the literature (Tokushima and Jarman 2010). In a normal phase the Pilliga Mouse is likely to be confined to primary habitat that consists of woodland or forests with a substrate suitable for burrowing (deep sandy soil), a short (generally less than one metre in height) diverse shrubby layer with a relatively high foliage projective cover and an open mid storey. These sites are generally high in plant diversity and are likely to provide a diverse diet of seeds fruits, insects and fungi that could support mice during normal phases when available food resources are likely to be lower in less suitable secondary habitat (Tokushima and Jarman 2010).

4.2 Distribution and abundance

The current literature on the Pilliga Mouse suggests that densities are usually less than five individuals per hectare except during irruption events, in which they can rise to an average density of 33.5 mice per hectare (Tokushima et al. 2008). While the capture/recapture rates during this survey were not sufficient to undertake an analysis of population densities using the MARK program a rough estimate of the number of individuals per hectare was calculated for PM08 (12 individuals per hectare) and for other sites where only one mouse was captured/detected (four individuals per hectare).

This suggests that population densities during 2013 were relatively low, compared to that found in previous studies in similar habitats within the Pilliga region. This is consistent with the hypothesis that the Pilliga Mouse population in the study area was in a normal phase rather than an irruption phase during the 2013 surveys. However, there are limitations to estimating densities based only on capture rates. There is likely to be an inherent under-estimation of density in this approach since it is unlikely that all members of a population would be captured in a single trapping session.

While most studies on population densities will be limited to some degree it is considered that estimates of population fluctuations in Tokushima et al. (2008) are likely to be the most accurate since surveys were undertaken over a number of years with a level of trapping effort that enabled some statistical analysis. Furthermore, in relation to habitat preference, the results of 2013 surveys seem consistent with Tokushima et al. (2008). Therefore, the best estimates of population densities in the study area can be made using densities estimated by Tokushima et al. (2008).

Based on population size estimates (Tokushima et al. 2008) the study area has the potential to carry up to 45,655 individuals in primary habitat alone (low density at 5 individuals per hectare). However, it should be noted that not all primary habitat patches have been surveyed, nor will the Pilliga Mouse occur in all patches of primary habitat at all times. Potential Pilliga mouse populations during irruption phases are expected to be an order of magnitude higher.

The results of the 2013 surveys have been incorporated into Pilliga Mouse habitat modelling (ELA 2015) and an updated map is shown in **Figure 2**. As noted in ELA (2015) primary habitat is predicted to be inhabited more permanently by the Pilliga Mouse, while secondary habitat is expected to be inhabited less readily, after fire or in successful breeding years. This suggests that the primary distribution of the Pilliga Mouse is likely to be restricted to particular habitats (primary habitats) in the south and east of the study area during normal phases.

While it is difficult to estimate population ranges and sizes, based on the results of the surveys and the habitat modelling there are five large general areas that support relatively intact patches of primary habitat. These include (**Figure 2**):

- Woodlands adjoining the floodplain of Bohena Creek.

- Woodlands on and adjoining the floodplain of Bibblewindi Creek.
- Woodlands on and adjoining the floodplain of Cowallah Creek.
- Large patches of woodland in the south-east of the study area in the upper catchment of Bibblewindi Creek.
- Scattered patches of woodland in the eastern portion of the study area.

The primary habitat along Bohena Creek, Bibblewindi Creek, Cowallah Creek and their tributaries are linked by areas of secondary habitat in a north-south direction which is likely to facilitate migration and immigration between populations. Vegetation between these three linear north-south oriented habitats generally consists of either shrubby or grassy woodlands or with clay loam soils and relatively low shrub diversity, which are unlikely to sustain the Pilliga Mouse in normal or non-irruptive phases. These areas of unsuitable habitat are likely to be used by the Pilliga Mouse for dispersal during periods of population irruption.

In contrast, the primary habitat in the south-east of the study is relatively large, non-linear and intact and is also connected to a mosaic of primary and secondary habitat in the east and north east of the study area. Therefore, the south and east of the study area may potentially support higher numbers of the Pilliga Mouse because a larger mosaic of primary and secondary habitat may be make it easier for individuals to breed and disperse. This configuration of habitat may also allow populations to be more resilient to disturbance events such as fire or poor seasonal condition, since it increases the likelihood that animals can access other areas of primary habitat during disturbance.

The landscape in the north of the study area changes gradually but dramatically to woodland on heavier soils, and with a predominately grassy understorey, which is considered unsuitable for the Pilliga Mouse. Within the study area, the highest densities and primary areas of habitat are likely to be shrubby woodlands with sandy soils in the south and south-east of the study area and on Bohena Creek, Bibblewindi Creek, Cowallah Creek and their tributaries.

5 Conclusion

Autumn and spring surveys identified the Pilliga Mouse in areas of both primary and secondary habitat in woodland near Bohena Creek and in the east of the study area.

The results of the habitat modelling for the Pilliga Mouse (ELA 2015) identified areas of primary and secondary habitat predominantly in the south and south east of the study area and adjacent to major watercourses such as Bohena Creek, Bibblewindi Creek and Cowallah Creek. Primary habitat included heathy woodland on sandy soils suitable for burrowing with a low and diverse shrubby layer and a diverse ground layer. Secondary habitat included shrubby and heathy woodland but with generally lower shrub diversity or cover.

The low capture rate of the Pilliga Mouse and the habitats in which it was detected is consistent with the suggestion that this species was in a normal phase, rather than an irruption phase during surveys in 2013. Low capture rates meant that the density of this species in the study area at the time of surveys could not be accurately identified. Estimates of population dynamics in the literature specify peak density (during population irruption) at between 15 to 90 mice per hectare, in comparison to low density (during normal times) which has been calculated at below 5 mice per hectare. It is estimated that the study area has the potential to carry 45,655 individuals in primary habitat. However, this is likely to be an over-estimation since it is unlikely that all patches would be were occupied at the same time

The north and north-west of the study area contains either grassy or shrubby woodlands on more fertile soils considered less suitable for burrowing and therefore is not likely to be considered habitat for the Pilliga Mouse. This species is not predicted to occur in these areas.

The Pilliga Mouse is not restricted to the study area, with a large number of existing records to the south, south-west and west of the study area within the Pilliga region. These records occur in a range of vegetation and habitat types and are connected to the mosaic of primary and secondary habitat that occurs in the south of the study area and along Bohena Creek, Bibblewindi Creek and Cowallah Creek. Individuals on the edges of the study area are likely to interact with other individuals by moving across these habitats outside of the study area, especially in irruption phases. The habitats in the study area are likely to form part of a wider area of habitat for the Pilliga Mouse that occurs within the Pilliga region.

The results of DNA analysis undertaken as part of this study support the genetic work previously conducted by Dr Ford for his PhD thesis which found there is no taxon corresponding to Pilliga Mouse (Ford 2003). A review of the status of this species is required.

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Appendix A: Survey Effort

Table 3: Autumn 2013 Week 1 Elliot, pitfall and hair tube surveys

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
PM01	Elliot trap (A-size)	26	6 May 2013	10 May 2013	4	104
	Elliot trap (E-size)	10	6 May 2013	10 May 2013	4	40
	Pitfall	3	6 May 2013	10 May 2013	4	12
PM02	Elliot trap (A-size)	26	6 May 2013	10 May 2013	4	104
	Elliot trap (E-size)	10	6 May 2013	10 May 2013	4	40
	Pitfall	3	6 May 2013	10 May 2013	4	12
PM03	Elliot trap (A-size)	26	6 May 2013	11 May 2013	5	130
	Elliot trap (E-size)	10	6 May 2013	11 May 2013	5	50
	Pitfall	3	6 May 2013	11 May 2013	5	15
PM05	Elliot trap (A-size)	26	6 May 2013	11 May 2013	5	130
	Elliot trap (E-size)	10	6 May 2013	11 May 2013	5	50
	Pitfall	3	6 May 2013	11 May 2013	5	15
PM08	Elliot trap (A-size)	26	6 May 2013	11 May 2013	5	130
	Elliot trap (E-size)	10	6 May 2013	11 May 2013	5	50
	Pitfall	3	6 May 2013	8 May 2013	2	6
PM11	Elliot trap (A-size)	26	6 May 2013	10 May 2013	4	104
	Elliot trap (E-size)	10	6 May 2013	10 May 2013	4	40
	Pitfall	3	6 May 2013	10 May 2013	4	12

Table 4: Autumn 2013 Week 2 Elliot, pitfall and hair tube surveys

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
PM09	Elliot trap (A-size)	26	27 May 2013	1 June 2013	5	130
	Elliot trap (E-size)	10	27 May 2013	1 June 2013	5	50
	Pitfall	3	27 May 2013	1 June 2013	5	15
PM10	Elliot trap (A-size)	26	27 May 2013	1 June 2013	5	130
	Elliot trap (E-size)	10	27 May 2013	1 June 2013	5	50
	Pitfall	3	27 May 2013	1 June 2013	5	15
PM12	Elliot trap (A-size)	26	27 May 2013	31 May 2013	4	104
	Elliot trap (E-size)	10	27 May 2013	31 May 2013	4	40
	Pitfall	3	27 May 2013	31 May 2013	4	12
PM04	Elliot trap (A-size)	26	27 May 2013	31 May 2013	4	104
	Elliot trap (E-size)	10	27 May 2013	31 May 2013	4	40
	Pitfall	3	27 May 2013	31 May 2013	4	12
PM06	Elliot trap (A-size)	26	27 May 2013	1 June 2013	5	130
	Elliot trap (E-size)	10	27 May 2013	1 June 2013	5	50
	Pitfall	3	27 May 2013	1 June 2013	5	15
PM07	Elliot trap (A-size)	26	27 May 2013	1 June 2013	5	150
	Elliot trap (E-size)	10	27 May 2013	1 June 2013	5	30
	Pitfall	3	27 May 2013	1 June 2013	5	15

Table 5: Autumn 2013 hair tube sites

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
HT19	Hair tube	20	7 May 2013	31 May 2013	24	480
HT20	Hair tube	20	7 May 2013	31 May 2013	24	480
HT21	Hair tube	20	8 May 2013	28 May 2013	20	180
HT22	Hair tube	20	7 May 2013	29 May 2013	21	220
HT23	Hair tube	20	7 May 2013	29 May 2013	21	220
HT24	Hair tube	20	9 May 2013	28 May 2013	19	180
HT25	Hair tube	20	7 May 2013	29 May 2013	21	220
HT26	Hair tube	20	8 May 2013	29 May 2013	20	200

Table 6: Spring 2013 Week 1 Elliot and pitfall surveys

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
MFb01	Elliot trap (A-size)	28	14 October 2013	18 October 2013	4	112
	Elliot trap (E-size)	8	14 October 2013	18 October 2013	4	32
	Pitfall	2	14 October 2013	18 October 2013	4	8
MFb02	Elliot trap (A-size)	28	14 October 2013	17 October 2013	3	84
	Elliot trap (E-size)	8	14 October 2013	17 October 2013	3	24
	Pitfall	2	14 October 2013	18 October 2013	4	8
MFb03	Elliot trap (A-size)	28	14 October 2013	18 October 2013	4	112
	Elliot trap (E-size)	8	14 October 2013	18 October 2013	4	32
	Pitfall	2	14 October 2013	18 October 2013	4	8
MFb04	Elliot trap (A-size)	28	14 October 2013	18 October 2013	4	112

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
	Elliot trap (E-size)	8	14 October 2013	18 October 2013	4	32
	Pitfall	2	14 October 2013	18 October 2013	4	8

Table 7: Spring 2013 Week 2 Elliot and pitfall surveys

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
MFb05	Elliot trap (A-size)	28	4 November 2013	8 November 2013	4	112
	Elliot trap (E-size)	8	4 November 2013	8 November 2013	4	32
	Pitfall (regular)	2	4 November 2013	8 November 2013	4	8
	Pitfall	2	4 November 2013	8 November 2013	4	8
MFb06	Elliot trap (A-size)	28	4 November 2013	7 November 2013	3	84
	Elliot trap (E-size)	8	4 November 2013	7 November 2013	3	24
	Pitfall (regular)	2	4 November 2013	8 November 2013	4	8
	Pitfall	2	4 November 2013	8 November 2013	4	8
MFb07	Elliot trap (A-size)	28	4 November 2013	8 November 2013	4	112
	Elliot trap (E-size)	8	4 November 2013	8 November 2013	4	32
	Pitfall (regular)	2	4 November 2013	8 November 2013	4	8
	Pitfall	2	4 November 2013	8 November 2013	4	8
MFb08	Elliot trap (A-size)	28	4 November 2013	7 November 2013	3	84
	Elliot trap (E-size)	8	4 November 2013	7 November 2013	3	24
	Pitfall (regular)	2	4 November 2013	8 November 2013	4	8
	Pitfall	2	4 November 2013	8 November 2013	4	8

Table 8: Spring 2013 hair tube sites

Site	Trap type	Trap number	Date set	Date collected	Number of nights	Trapping effort
HT27	Hair tube	10	15 October 2013	6 November 2013	22	220
HT28	Hair tube	10	17 October 2013	7 November 2013	21	210
HT29	Hair tube	10	16 October 2013	6 November 2013	21	210
HT30	Hair tube	10	16 October 2013	6 November 2013	21	210
HT31	Hair tube	20	17 October 2013	6 November 2013	20	200

Appendix B: Survey sites

Table 9: Autumn survey sites

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
PM01	Broombush	51–100%	Clay loam	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)
PM02	Broombush	41–50%	Clay loam	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)
PM03	Heathy woodland	10–20%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)
PM04	Heathy woodland	10–20%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 4 (27 May – 1 June)
PM05	Heathy woodland	21–40%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
PM06	Heathy woodland	21–40%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 4 (27 May – 1 June)
PM07	Heathy woodland	41–50%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 4 (27 May – 1 June)
PM08	Heathy woodland	41–50%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)
PM09, PM10	Heathy woodland	51–100%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 4 (27 May – 1 June)
PM11	Riparian woodland	<10%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 1 (6-11 May)
PM12	Riparian woodland	<10%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (small) Hair tubes	Week 4 (27 May – 1 June)

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
HT21	Heathy woodland	21–40%	Sandy	Hair tubes	Week 1 to Week 4 (6 May – 1 June)
HT22	Shrubby woodland	21–40%	Sandy	Hair tubes	Week 1 to Week 4 (6 May – 1 June)
HT23	Heath	51–100%	Clay loam	Hair tubes	Week 1 to Week 4 (6 May – 1 June)
HT24	Shrubby woodland	21–40%	Sandy	Hair tubes	Week 1 to Week 4 (6 May – 1 June)
HT25	Heathy woodland	21–40%	Sandy	Hair tubes	Week 1 to Week 4 (6 May – 1 June)
HT26	Heathy woodland	21–40%	Sandy	Hair tubes	Week 1 to Week 4 (6 May – 1 June)

Table 10: Spring survey sites

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
MFb01	Shrubby Woodland	Not recorded	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 1 (14 – 18 October)
MFb02	Woodland	<10%	Clay loam	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 1 (14 – 18 October)
MFb03	Heathy Woodland	41-50%	Sandy	Elliot trapping (A-size)	Week 1 (14 – 18 October)

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
				Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	
MFb04	Heathy Woodland	10-20%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 1 (14 – 18 October)
MFb05	Shrubby Woodland	10-20%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 4 (4 – 8 November)
MFb06	Shrubby Woodland	10-20%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 4 (4 – 8 November)
MFb07	Shrubby Woodland	21-40%	Sandy	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 4 (4 – 8 November)
MFb08	Shrubby Woodland	41-50%	Clay loam	Elliot trapping (A-size) Elliot trapping (E-size) Pitfalls (regular) Pitfalls (small)	Week 4 (4 – 8 November)
HT27	Shrubby Woodland	Not recorded	Sandy	Hair tubes	Week 1 to Week 4 (15 Oct

Site	Vegetation Structure	Shrub density	Soil substrate	Survey technique	Timing
					– 6 November)
HT28	Woodland	<10%	Clay loam	Hair tubes	Week 1 to Week 4 (15 Oct – 6 November)
HT39	Heathy Woodland	41-50%	Sandy	Hair tubes	Week 1 to Week 4 (15 Oct – 6 November)
HT30	Shrubby Woodland	-	-	Hair tubes	Week 1 to Week 4 (15 Oct – 6 November)
HT31	Shrubby Woodland	10-20%	Sandy	Hair tubes	Week 1 to Week 4 (15 Oct – 6 November)

Appendix C: Weather conditions

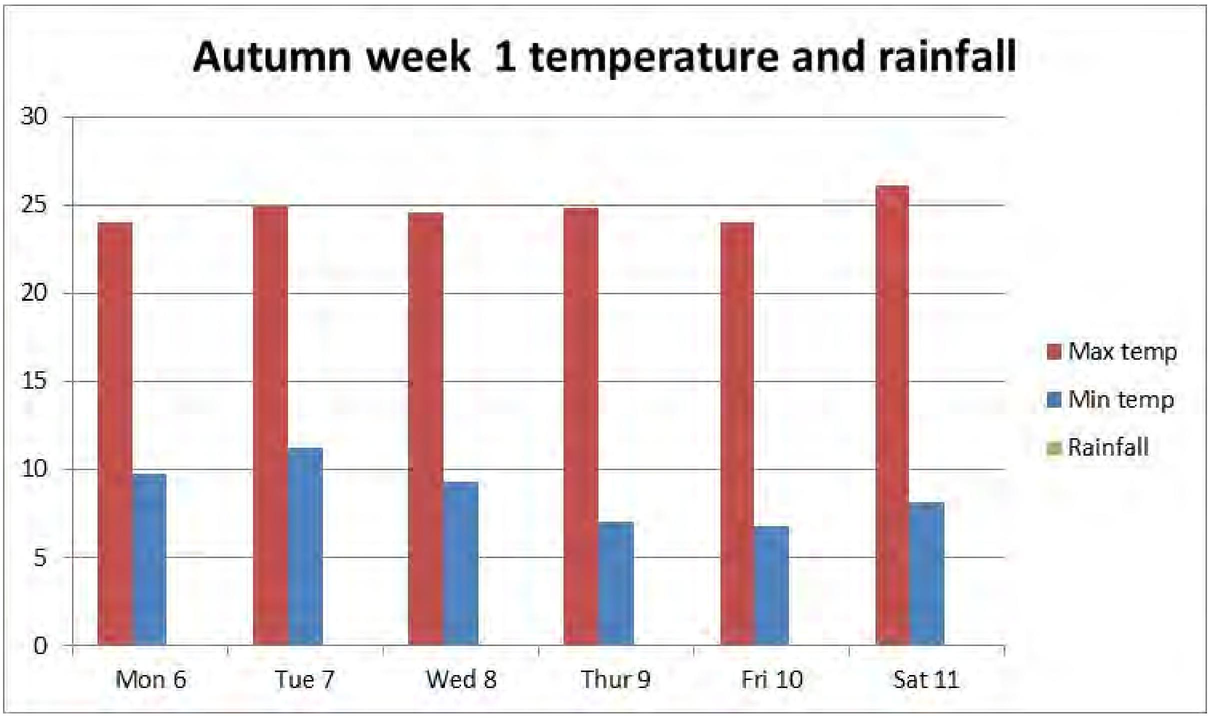

Figure 3 Autumn week 1 temperature and rainfall

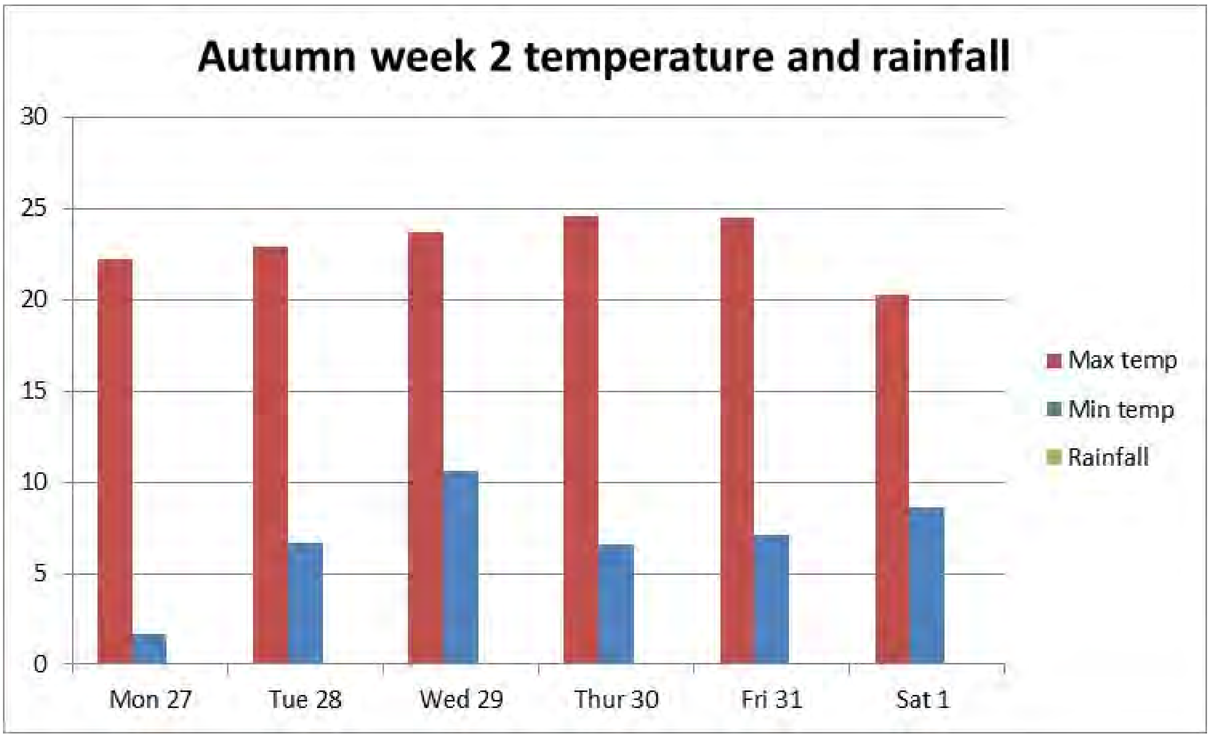

Figure 4 Autumn week 2 temperature and rainfall

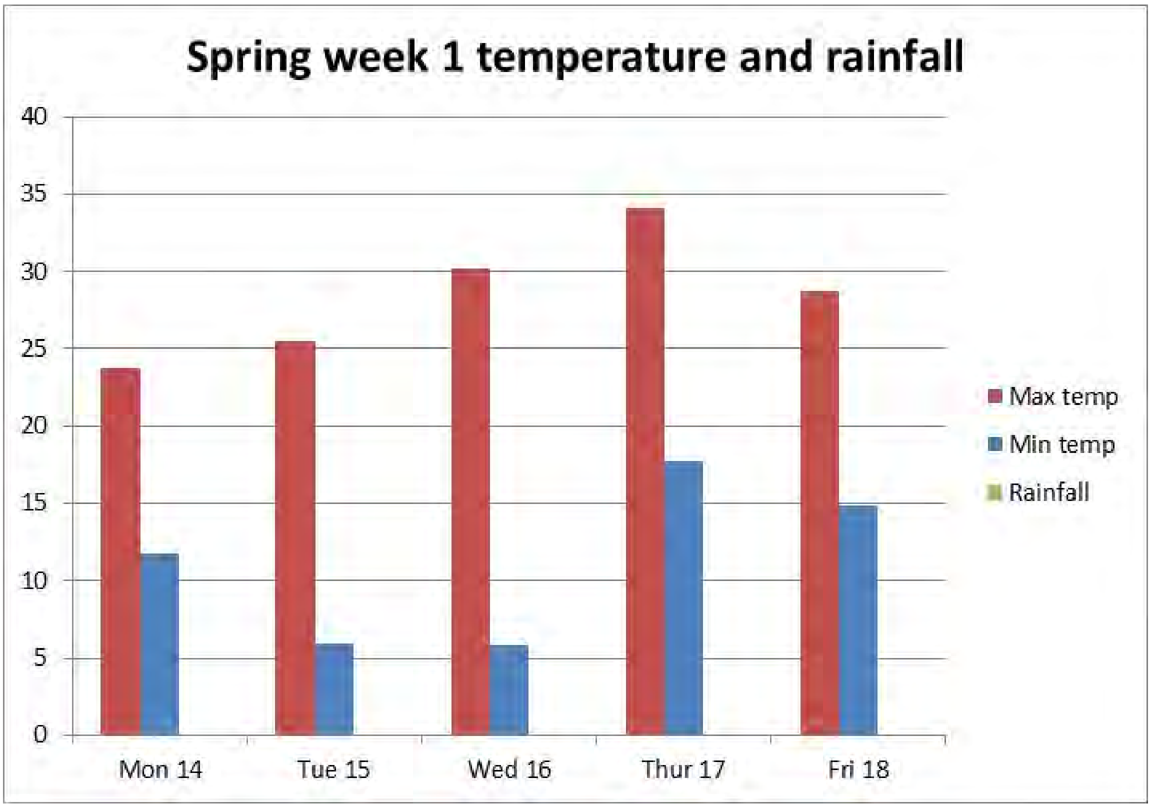

Figure 5 Spring week 1 temperature and rainfall

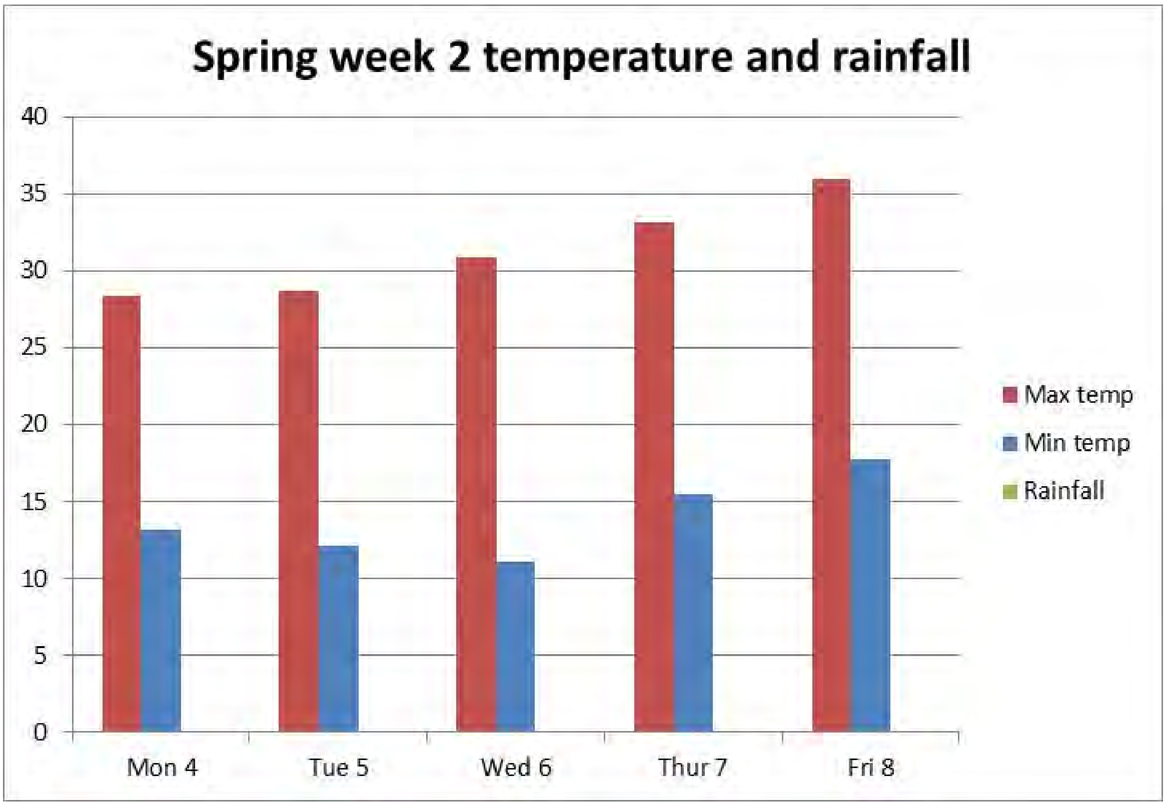

Figure 6 Spring week 2 temperature and rainfall

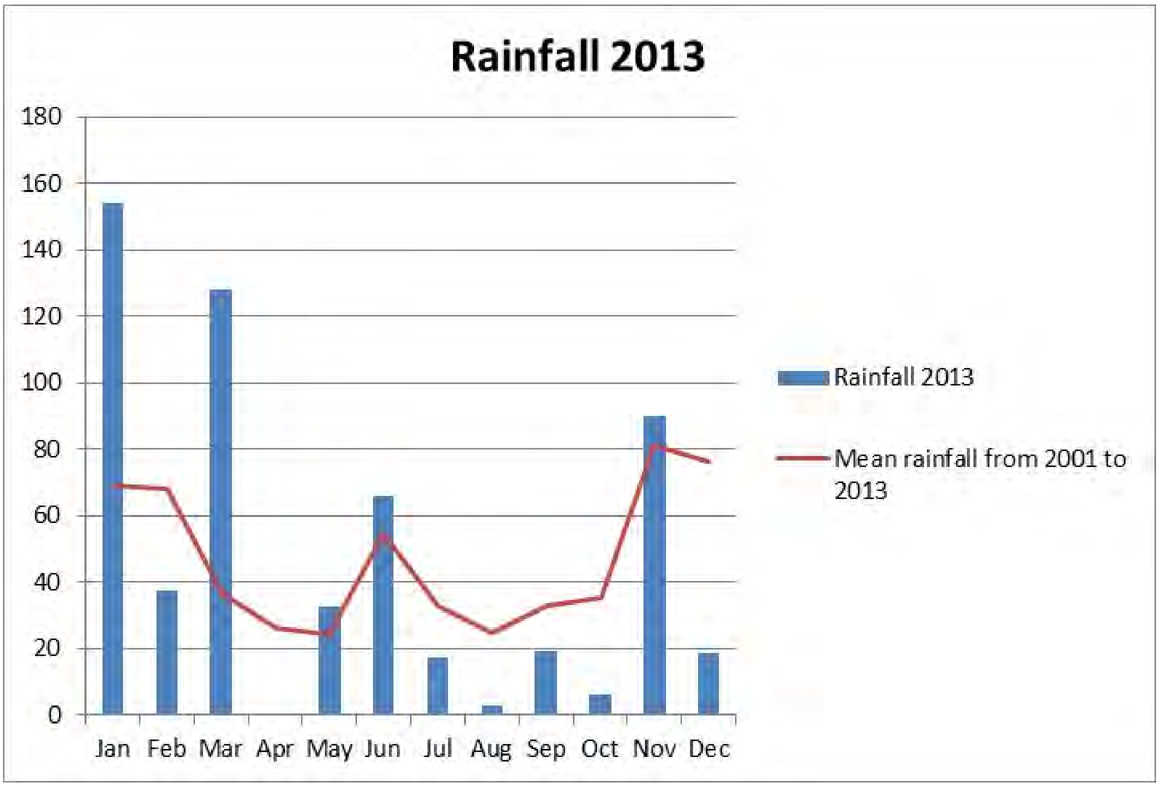

Figure 7: Rainfall 2013

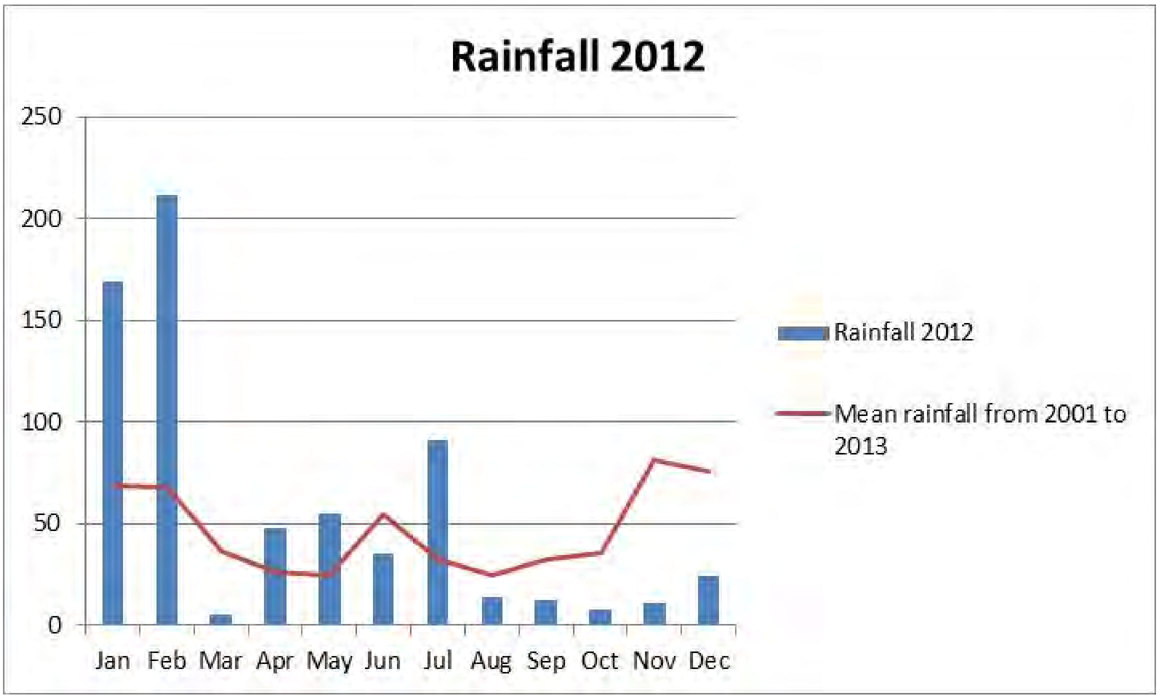

Figure 8: Rainfall 2012

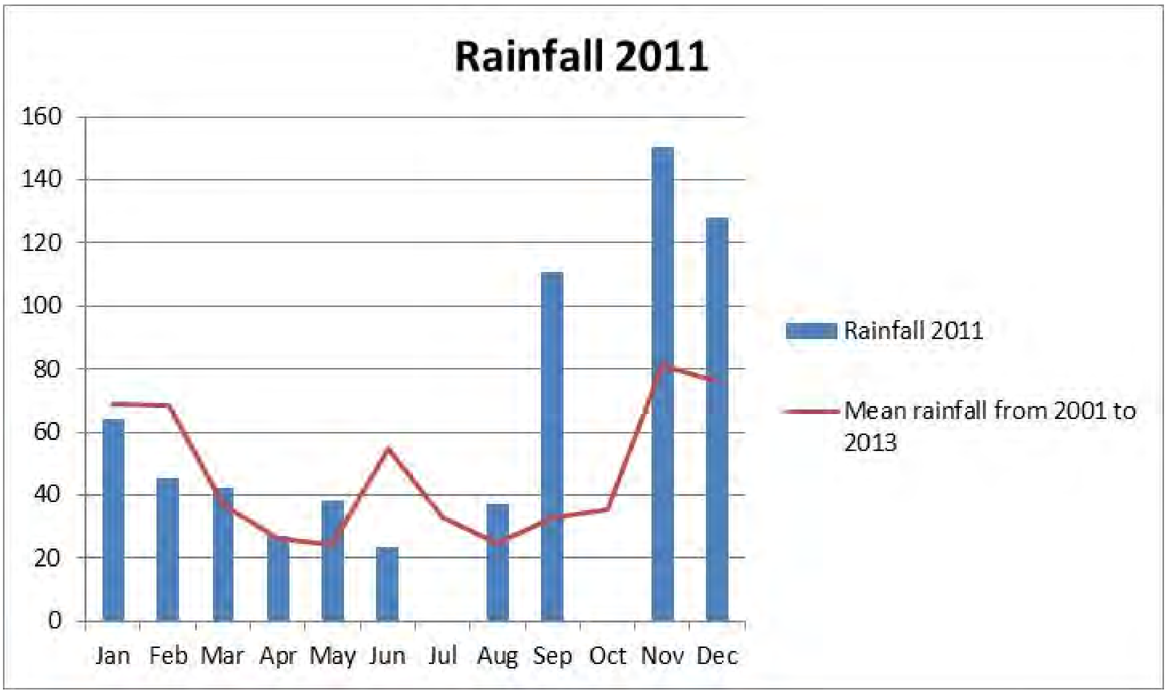

Figure 9: Rainfall 2012

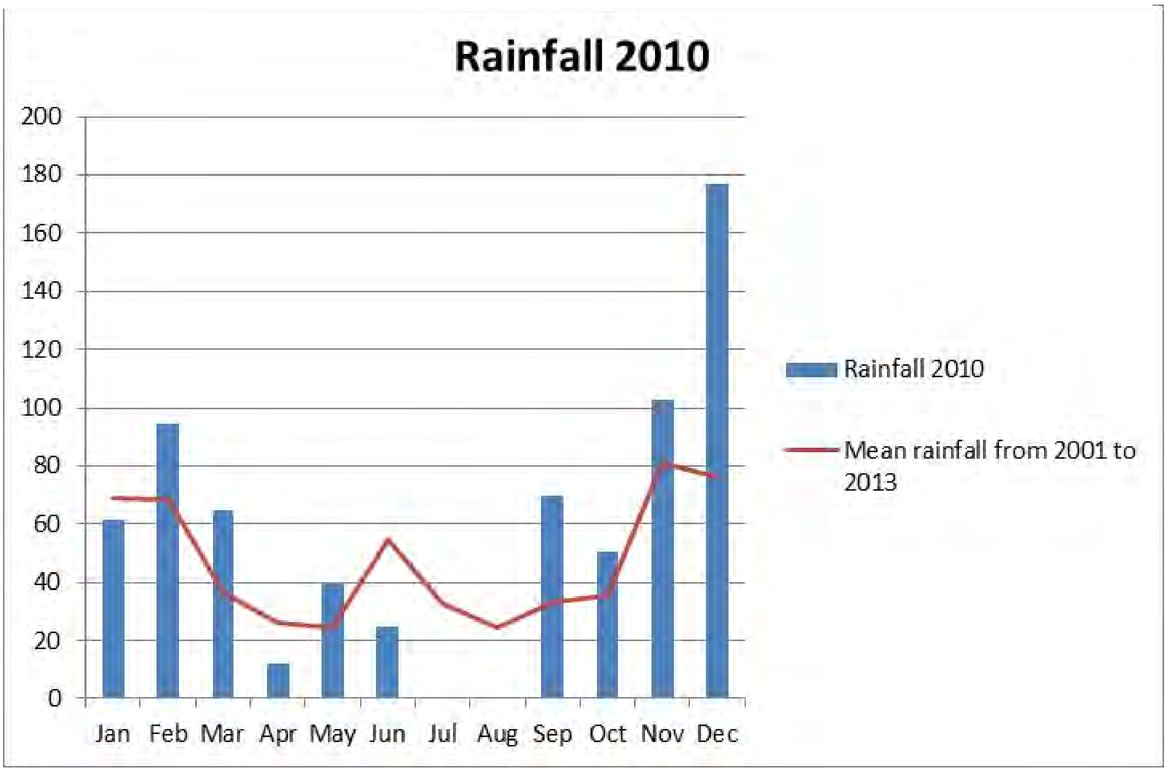

Figure 11: Rainfall 2010

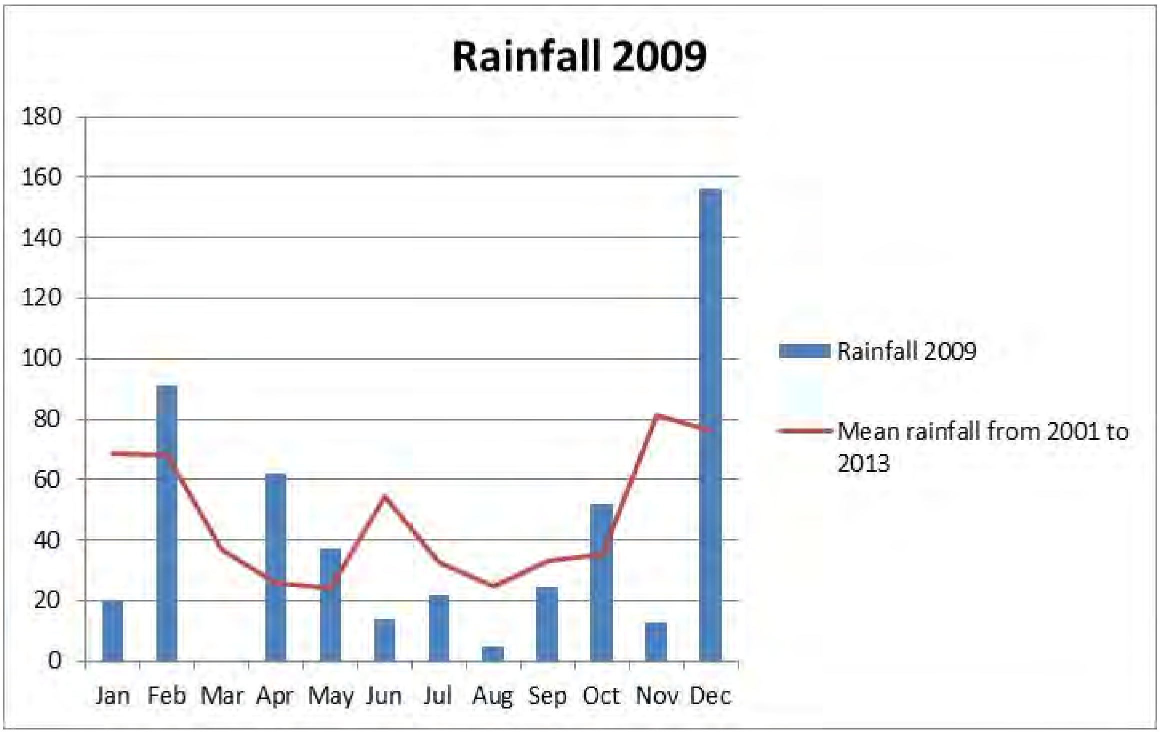

Figure 12: Rainfall 2009

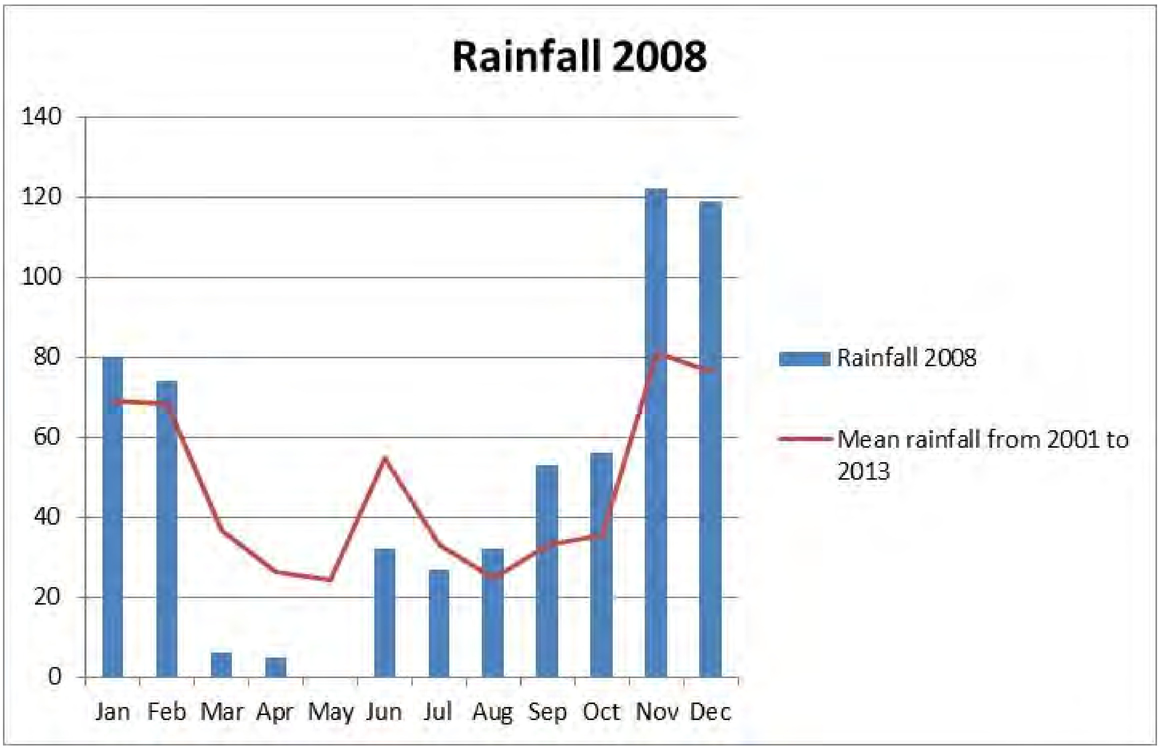

Figure 13: Rainfall 2008

Appendix D: Pilliga Mouse habitats

Table 11: Pilliga Mouse habitats

Report	Survey dates	Area surveyed	Habitat type
Jeffries and Fox (2001)	Four surveys: 1976, 1977, 1979, 1988	Pilliga East State Forest, Timmallallie Creek, Pilliga Nature Reserve	*Eucalyptus macrorhyncha*/*Eucalyptus rossii*/*Callitris endlicheri* forest *Eucalyptus blakelyi*/*Angophora floribunda* woodland in creeklines with *Callistemon* spp. and *Leptospermum* spp.
Paull (2002)	Two surveys: 1997/1998 and 2000	Pilliga State Forest (eastern portion)	Mature *Melaleuca uncinata* Scrub* Regrowth *Melaleuca uncinata* Scrub* Recently burnt gullies* *Acacia burrowii*/*Corymbia trachyphloia* scrub* Shrubby woodland *Acacia triptera* scrub *Eucalyptus viridis* mallee *Eucalyptus crebra*/*Acacia tindaleae* scrub Recently burnt scrub
Tokushima et al. (2008), Tokushima and Jarman (2008), Tokushima and Jarman (2010)	Four surveys: 1997, 1999, 2000, 2001	Pilliga Nature Reserve	*Angophora*/*Eucalyptus*/*Callitris* woodland with a diverse mid- and understorey of woody shrubs and a very sparse ground cover (but with much litter)
Paull (2009)	Three surveys: 1993/1994, 1998, 1999/2000	Pilliga East State Forest	*Melaleuca uncinata* scrub/shrubland association *Corymbia trachyphloia*/*Acacia burrowii* low woodland to tall scrub Shrubby mixed woodlands(*Eucalyptus blakelyi, Eucalyptus crebra*, *Eucalyptus fibrosa, Eucalyptus pilligaensis,* Corymbia *trachyphloia,*) Mature *Eucalyptus viridis* mallee scrub *Eucalyptus crebra* forest *Acacia tindaleae* scrub Riparian woodlands of *Eucalyptus blakelyi* and *Angophora costata* Rocky areas of *Eucalyptus fibrosa* and *Callitris endlicheri*

Appendix E: DNA analyses

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Wildlife Genetics and Microscopy Unit Results Report

Case No: AM096	**Date:** 29/08/2013	**Service:** Species Identification
Species: Suspected *Pseudomys pilligaensis*		
Client contact: Martin Sullivan, Eco-Logical Australia		
Report prepared by: Dr Greta Frankham		**Report checked by:** Dr Rebecca Johnson
Laboratory work conducted by: Dr Greta Frankham		

Dear Martin,

Four biological samples sent by you for analysis were received by the Wildlife Genetics and Microscopy Unit at the Australian Museum on the 19th of July 2013. DNA was successfully extracted from the unknown sample using our standard laboratory protocols (see page 4). Based on the information you provided regarding suspected species, two mitochondrial (mtDNA) gene regions were sequenced and compared to publically available published data and reference sequences generated from vouchered specimens from the Australian Museum Tissue Collection to confirm species identification. The two sources of scientific literature used in this case were:

Cytochrome oxidase b - Kocher et al. (1989). Dynamics of mitochondrial DNA evolution in animals: Amplification and sequencing with conserved primers. *Proc. Nat. Acad. Sci. USA* Vol. 86, pp. 6196-6200.

Control Region - Rowe et al. (2011). Population structure, timing of divergence and contact between lineages in the endangered Hastings River mouse (*Pseudomys oralis*) *Aust. J. Zool.* Vol. 59, pp. 186–200

In addition, Dr Fred Ford, a recognised expert on molecular determination of *Pseudomys* species in Australia was consulted regarding our results.

Based on the samples provided, the tests that were used, and consultation with Dr Ford, the sequence identity of the unknown to the known reference sequences were sufficient for species identification. The results table, below, indicates our species determination and which reference species the mtDNA of the unknown samples are most consistent with.

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AM Sample ID	Client Sample ID	Species (Determined by DNA analysis)
AM096_1	Sample 1 collected 8/5/13	*Pseudomys 'pilligaensis'* (*P. delicatulus*)*
AM096_2	Sample 2 collected 9/5/13	*Pseudomys 'pilligaensis'* (*P. delicatulus*)*
AM096_3	Sample 3 collected 11/5/13	*Pseudomys 'pilligaensis'* (*P. delicatulus*)*
AM096_4	Sample 4 collected 11/5/13	*Pseudomys 'pilligaensis'* (*P. novaehollandiae *)*
AM096_6 *P. bolami*	*AM reference sample*	*P bolami*
AM096_7 *P. bolami*	*AM reference sample*	*P. bolami*
AM096_8 *P. bolami*	*AM reference sample*	*P. bolami*
AM096_9 *P. novaehollandiae*	*AM reference sample*	*P. novaehollandiae*
AM096_10 *P. novaehollandiae*	*AM reference sample*	*P. novaehollandiae*
AM096_12 *P. novaehollandiae*	*AM reference sample*	*P. novaehollandiae*
AM096_13 *P. novaehollandiae*	*AM reference sample*	*P. novaehollandiae*
AM096_14 *P. pilligaensis*	*AM reference sample*	*P. 'pilligaensis' (P. delicatulus*)*
AM096_15 *P. delicatulus*	*AM reference sample*	*P. delicatulus*
AM096_17 *P. delicatulus*	*AM reference sample*	*P. delicatulus*
AM096_18 *P. delicatulus*	*AM reference sample*	*P. delicatulus*
AM096_19 *P. hermannsbergensis*	*AM reference sample*	*P. hermannsbergensis*

* Species with which mtDNA is most consistent.

Important note on the taxonomy of *Pseudomys pilligaensis*: While some authors have described *Pseudomys pilligaensis* as an independent species (based on morphological and electrophoretic characters) and it is recognised and listed under the NSW Threatened Species Act as Vulnerable. Recent molecular evidence does not support this distinction (F. Ford pers. comm.) as the level of interspecies difference we would typically observe between distinct species is not seen.

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It is likely that the *Pseudomys* population in the Pilliga represent a population of *P. delicatulus* that, in the past, has hybridised with a population of *P. novaehollandiae* (F. Ford pers. comm.). The DNA sequence results obtained from the unknown samples received for this analysis were consistent with this hypothesis. Samples AM096_1-3 exhibited mtDNA haplotypes most consistent with *P. delicatulus* and sample AM096_4 exhibited mtDNA haplotypes most consistent with *P. novaehollandiae.* Therefore, given the outcomes of our molecular results coupled with your statement on the locality of sample collection we have identified these samples as the species that is currently considered by *Pseudomys* experts, and listed under the NSW Threatened Species Act, as *Pseudomys pilligaensis.* The legitimacy of this species name is, however, the subject of ongoing research.

Please feel free to contact us if you wish to discuss these results further.

Yours sincerely,

Rebecca Johnson

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Determination of species identity based on mitochondrial DNA sequencing.
Brief summary of our workflow:

1. Your sample arrives and details are logged.

2. The sample is stored at -20 degrees Celsius until it can be processed.

3. Total genomic DNA is extracted from two separate sources from your sample. The primary source is taken from blood or tissue (if available).

4. Polymerase Chain Reaction (PCR) is used to amplify several target genes that have been chosen as good identifiers for the taxa in question. We have generalised amplification conditions and reagents optimized for birds, bats, mammals, amphibians and reptiles.

5. The short PCR products amplified from these targets are purified and sequenced. Sequencing is sub-contracted to the Australian Genome Research Facility, which is a NATA accredited sequencing facility.

6. DNA analysis is used to compare your unknown sequence with data from large international public databases (Genbank and/or BOLD) as well as from vouchered reference material held by the Australian Museum.

   The Wildlife Genetics & Microscopy Unit has access to thousands of specimens in Australia's oldest zoological reference collection (the Australian Museum) as well as museum taxonomists, ensuring accurate and trustworthy results.

   Disclaimer: This report is not to be used for court or legal purposes. A court statement can be prepared upon request.

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F7: Regional Koala assessment

KOALA REFUGES IN THE PILLIGA FORESTS

May 2014

Front cover photograph: Riparian Red Gum woodland targeted for koala surveys in the Pilliga. Observer searching for koala faecal pellets. Note typical dry sandy creek bed with no free water available. A koala was observed at this site (Photo Matthew Stanton).

EXECUTIVE SUMMARY

Context

The north-western slopes region of NSW has experienced below-average rainfall during the "millennium" drought of 2001-2009, and more recently in 2012-2014, combined with an increasing frequency of above-average very hot (>40ºC) temperatures. These factors are thought to be ultimately responsible for the catastrophic decline observed in Koala distribution and abundance throughout the Pilliga forests over the past 15 years. Identifying and locating the key habitat and/or climate refuge areas where koalas have been able to persist throughout this period, and from which population recovery may occur, is regarded as information of great significance to conservation and forest managers.

Aims

The objective of this work was to identify and locate important habitat and/or climate refuges for the Koala in the context of a widespread decline in the abundance of this species throughout the region.

Methods

The results of recent plot-based surveys were combined with existing ecological understanding of koala habitat in the Pilliga to focus new survey efforts in areas where koalas were considered most likely to occur. Priority areas for survey were identified based on the distribution of selected riparian forest vegetation types and their co-incidence with sections of the major creek systems, including semi-permanent waterholes, in the Pilliga where koalas have been recorded previously. These linear strips of riparian Red Gum woodland were searched on foot by two observers at night and during the afternoon on the same day to detect the presence of koalas. Three teams (six observers in total) each searched approximately 3-4 km of riparian woodland per night for 11 nights. Nocturnal searches included spotlighting and passive listening for calling animals, as well as inspection of the sandy creek-bed below over-hanging trees for koala faecal pellets. Afternoon searches involved locating koala faecal pellets and scratches on trees as well as looking for koalas.

Key Results

Ten widely-spaced koalas were observed during the survey and koala faecal pellets were observed at a further 81 sites, many of which were clustered at particular locations. All records of the koala were located in two major creek systems and their tributaries (Baradine Creek and Etoo Creek). Additional signs of recent koala activity were found in Talluba and Rocky (Nth) Creeks. No koalas or signs of their recent activity were located in the creek lines of the Pilliga East State Forests or Conservation Areas.

Conclusions

These results confirm that a catastrophic decline has occurred in koala population size and distribution over the past 15 years. The riparian forest communities targeted for survey in this study did provide current habitat for the koala, but their capacity to support significant relict populations appears to have been limited. The exact cause of the koala population decline remains unresolved. Information deficiencies are outlined.

CONTENTS

1 INTRODUCTION

1.1 Context

The north-western slopes region of NSW has experienced below-average rainfall during the “millennium” drought of 2001-2009, and more recently during a very dry spell in 2012-2014, combined with an increasing frequency of above-average very hot (>40ºC) temperatures (Commonwealth Bureau of Meteorology for Baradine Forestry Office 1944-2014). These factors are thought to be ultimately responsible for the catastrophic decline observed in Koala distribution and abundance throughout the Pilliga forests over the past 15 years (Kavanagh and Barrott 2001, Kavanagh and Barrott-Brown 2014).

The aims of the present study were to identify and locate the key habitat and/or climate refuge areas where koalas have been able to persist throughout this period and from which population recovery may occur. This information is regarded as of great significance to conservation and forest managers. Santos Ltd also wishes to know where these significant koala refuges are located in the Pilliga forests, and has provided funding to staff from Niche Environment and Heritage (Niche) and EcoLogical Australia (ELA) to conduct targeted searches within the most likely areas.

The Pilliga forests (535,000 ha) of north-western New South Wales near Coonabarabran, Baradine and Narrabri (149° 07’E, 30° 45’S) have a long and continuing history of timber harvesting dating back more than a century which was preceded by unsuccessful attempts in the mid-1800s to establish a sustainable wool production industry (Rolls 1981, Van Kempen 1997, Whipp *et al*. 2009). The semi-arid climate and unsuitability of the soils for agriculture (Humphreys *et al*. 2001, Hesse and Humphreys 2001) have combined to protect the Pilliga forests (a mixture of Cypress Pines and Eucalypts), such that this area is now the single largest remaining tract of native forest and woodland in NSW west of the Great Dividing Range. The Pilliga forests now represent a significant reservoir for native plants and animals in the region, and in south-east Australian woodlands more generally, providing habitat for many species that are now threatened due to surrounding clearing for agriculture (Paull and Date 1999, Kavanagh and Barrott 2001, Date *et al*. 2002, Kavanagh and Stanton 2009). Recent changes in land tenure have resulted in half of this area continuing to be managed for timber production, and potentially for coal seam gas extraction, with the other half allocated primarily to nature conservation.

Ongoing threats to biodiversity conservation include fire, introduced predators and vehicular traffic within the Pilliga forest landscape (Dique *et al*. 2003, Lunney *et al*. 2007, Taylor and Goldingay 2010, Semeniuk *et al*. 2012). However, of potentially greater long-term significance, are the more frequent and extended periods of high temperature and altered rainfall regimes associated with climate change. Changes to the fire regime, through increased fire frequency and intensity, are also likely to occur as a consequence of climate change. The koala is an iconic species whose distribution and habitat is predicted to contract markedly in semi-arid regions such as the Pilliga under a future hotter and drier climate (Adams-Hosking *et al*. 2011). Koala populations are well known to be sensitive to drought and to extended periods of hot weather (Gordon *et al*. 1988, Seabrook *et al*. 2011, Lunney *et al*. 2012) and koalas are known to take extraordinary measures to avoid direct sunlight on hot, dry days (Kavanagh *et al*. 2007, Ellis *et al*. 2010). Higher concentrations of atmospheric CO_2 associated with climate change may also indirectly affect koalas through a reduction in the nutritional quality of the foliage of their *Eucalyptus* food trees (Lawler *et al*. 1997).

There is concern that koala populations in the Pilliga, and in many other forests west of the Great Dividing Range, have contracted significantly during the recent severe droughts and associated prolonged periods of very high temperatures between 2001-2014 (Seabrook *et al*. 2011, Kavanagh and Barrott-Brown 2014). A 2006 wildfire that burnt large areas in the Central Pilliga forests reduced koala habitat at that time in areas that had remained unburnt for many decades. Effective conservation and management of this species may depend on the identification and location of key refuge areas where koalas have been able to persist throughout this period, and from which population recovery may occur. Effective management of these habitat refuges is likely to become more important in the face of increasing climate change.

1.2 Project objectives

The objective of this work was to identify and locate important habitat and/or climate refuges for the Koala in the context of a general and widespread decline in the abundance of this species throughout the Pilliga region.

In particular, we aimed to:

- survey a number of riparian forest locations that were expected to be among those areas most resilient to drought and high temperatures, based on recent (2013) survey results and ecological understanding of koala habitat requirements, and thus most likely to be where any relictual numbers of koalas may occur; and to,
- document the locations that are found currently, or have been recently, occupied by koalas.

2 METHODS

2.1 Study Area

The Pilliga Forests were considered as a Koala 'hotspot', with estimates of up to 15,000 Koalas within the area in the mid 1990s and early 2000s, with areas often supporting high koala densities (Barrott 2001, Kavanagh and Stanton unpublished data). Recent, stratified and repeated, plot-based surveys have shown that koala distribution and abundance have contracted and declined dramatically in the Pilliga forests over the past 15 years (Kavanagh and Barrott-Brown 2014, and other unpublished data). The surveys conducted by Kavanagh and Barrott-Brown (2014) observed only one living koala on survey plots, suggesting that a significant decline had occurred. The present study sought to capitalise on these results, and previous ecological understanding of koala habitat in the Pilliga (Kavanagh *et al*. 2007), by deliberately focusing survey efforts for koalas in the "most likely areas".

The preferred food trees of the koala in the Pilliga forests are Pilliga Box *Eucalyptus pilligaensis* and one of several species of Red Gums (including *E. blakelyi, E. chloroclada* and/or *E. camaldulensis*), with White Cypress Pine (*Callitris glaucophylla*) and Rough-barked Apple (*Angophora floribunda*) providing the principal diurnal shelter, particularly in summer (Kavanagh *et al*. 2007). The Red Gums listed above have a closer affinity with sandy riparian zones (creeklines and small billabongs) where soil moisture and the possible presence of free water is likely to be greater than in the non-riparian areas where Pilliga Box (and other tree species) is most likely to occur. Accordingly, riparian areas, particularly those lined with mixed *Callitris-Angophora-Eucalyptus* forest types dominated by *E. blakelyi, E. chloroclada* and/or *E. camaldulensis*, were targeted in this study as being among the most likely areas providing refuge for koalas from drought and hot daily temperatures.

The two principal vegetation mapping systems and data layers covering the Pilliga forests are the Lindsay (1967) forest types used by the Forestry Corporation of NSW (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/389807/Forest-Types-of-the-NSW-Cypress-Pine-Zone.pdf, accessed 14 May 2014) and the more recent, but coarser resolution, Regional Vegetation Communities of the Namoi River Catchment (http://www.namoi.cma.nsw.gov.au/416845.html?2 accessed 14 May 2014) (Fig. 1). From these data sources, two RVCs were selected and mapped: #96 Blakely's Red Gum riparian woodland and #20 Rough-barked Apple – Blakely's Red Gum riparian grassy woodlands. These areas were overlain with similar vegetation communities derived from the finer-scale resolution Lindsay forest types, including vegetation types PBO, PAB, KURRICAB, PgBP, BOP, BC, BCA, BCP, BPg, BA, BAP, BP, BAC, B, AB, PB, PCB and PBA. In the Lindsay classification, "B" indicates *E. blakelyi*, "P" indicates *C. glaucophylla*, "A" indicates *A. floribunda*, "Pg" indicates *E. pilligaensis*, "C" indicates Narrow-leaved Ironbark *E. crebra*, "O" indicates Bull Oak *Allocasuarina luehmannii* and "KURRI" indicates Kurrajong *Brachychiton populneus*. Most of the areas thus mapped co-incided, as expected, with the major riparian systems and their tributaries throughout the Pilliga (Fig. 2).

Priority areas for survey were identified, taking into account the major creek systems where koalas have been recorded previously (e.g. Baradine Creek on the edge of West Pilliga, Etoo Creek in Central Pilliga and Borah Creek in East Pilliga), and the locations of semi-permanent waterholes and forest dams (Fig. 3). A subset of these “priority” areas was sampled because there was not enough time available to survey them all, but we prioritised our search efforts to ensure broad spatial coverage of all areas and to maximise logistical efficiency.

2.2 Survey methods

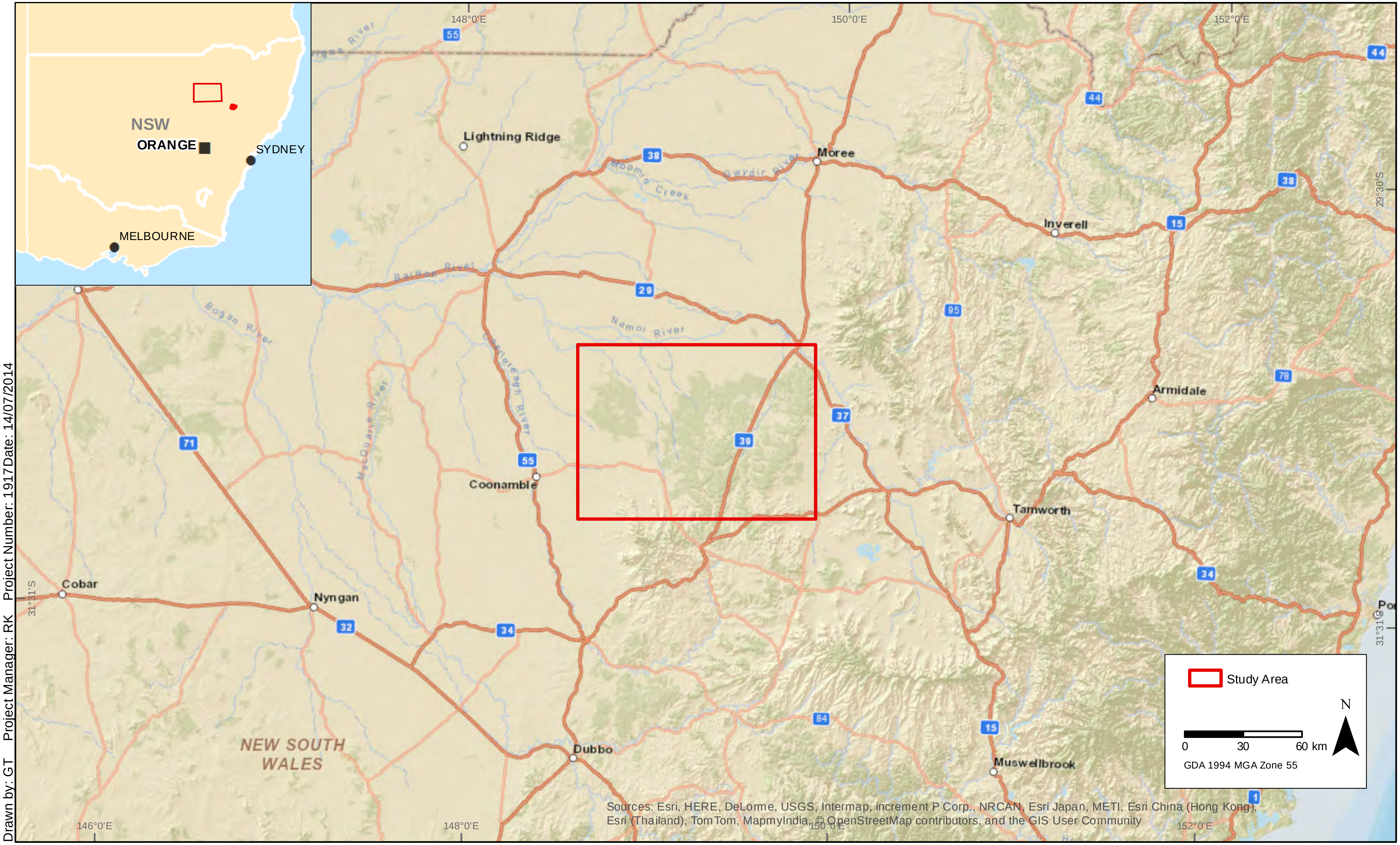
The emphasis in the present study was to obtain records of individual koalas known to be alive at the time of the survey. The only method that was considered effective to provide information on this was via direct observation, especially using spotlighting, as scat searches, without laboratory analyses of individual scats, would only provide information about whether an area had been used by a koala at some time in the previous few months. Thus, we placed secondary importance upon diurnal (and nocturnal) searches for koala faecal pellets, which could be several months old and deposited by an unknown number of individuals. Consequently, pellet searches in this study were not exhaustive, resulting only in a sample of the locations utilised by koalas in recent months (the approximate duration of decay in koala pellets in this environment). Nonetheless, the sand underneath most red gum trees and shelter trees lining the banks of the dry creek-lines in the Pilliga was searched during the afternoon or evening for koala faecal pellets and this provided a useful indicator of koala activity and/or occupancy in each search area. Given the time of year (autumn) when surveys were undertaken in the present study, it was considered that call playback would be relatively ineffective and so this method was not used.

Each “site”, typically a linear strip of riparian forest or woodland, was searched on foot by two observers at night and, for approximately half of the sites, also during the afternoon on the same day. Afternoon searches involved careful inspection of canopy trees for the presence of koalas, and searching for koala faecal pellets and scratches on trees located near the creek bank. Nocturnal searches included spotlighting and passive listening for calling animals, as well as inspection of the sandy creek-bed below over-hanging trees for koala faecal pellets. Koala remains were also searched for.

Most searches were confined to approximately 100 m wide buffers either side of selected creeks (Fig. 3), but the “effective survey area” when spotlighting was limited to a perpendicular distance of approximately 30-40 m either side of the observers.

Three teams (six observers in total) each searched approximately 3-4 km of riparian forest/woodland per night, returning to the starting point via a similar or a parallel route. GPS track logs recorded the complete survey effort for each team (Fig. 3). Additional spotlighting surveys were undertaken by car along selected forest roads and tracks. In all surveys, direct evidence of koala presence at the time of the survey was sought so that estimates of minimum population size could be made where this was appropriate. All surveys were undertaken on 11 afternoons and evenings between 28 April and 8 May 2014. Surveys were conducted from approximately 2 pm to midnight each day.

Drawn by: GT Project Manager: RK Project Number: 1917 Date: 14/07/2014



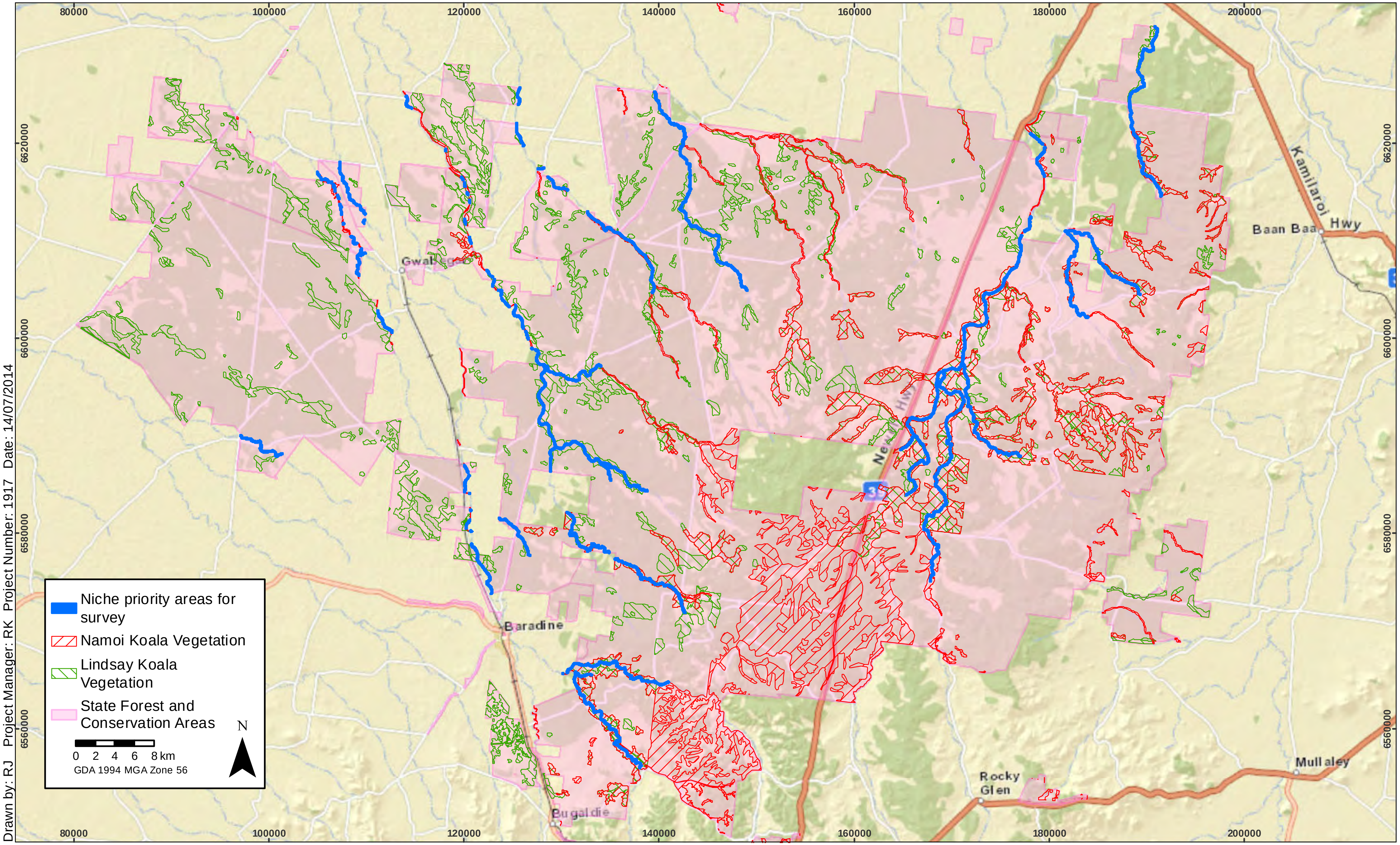
Study Area

Project 1917: Koala refuges in the Pilliga

FIGURE 1

Path: T:\spatial\projects\a1900\a1917_PilligaKoala\Maps\1917_Figure_1_StudyArea.mxd

Drawn by: RJ Project Manager: RK Project Number: 1917 Date: 14/07/2014



Distribution of predicted best habitat for the koala using two vegetation map systems, and Niche priority areas for survey

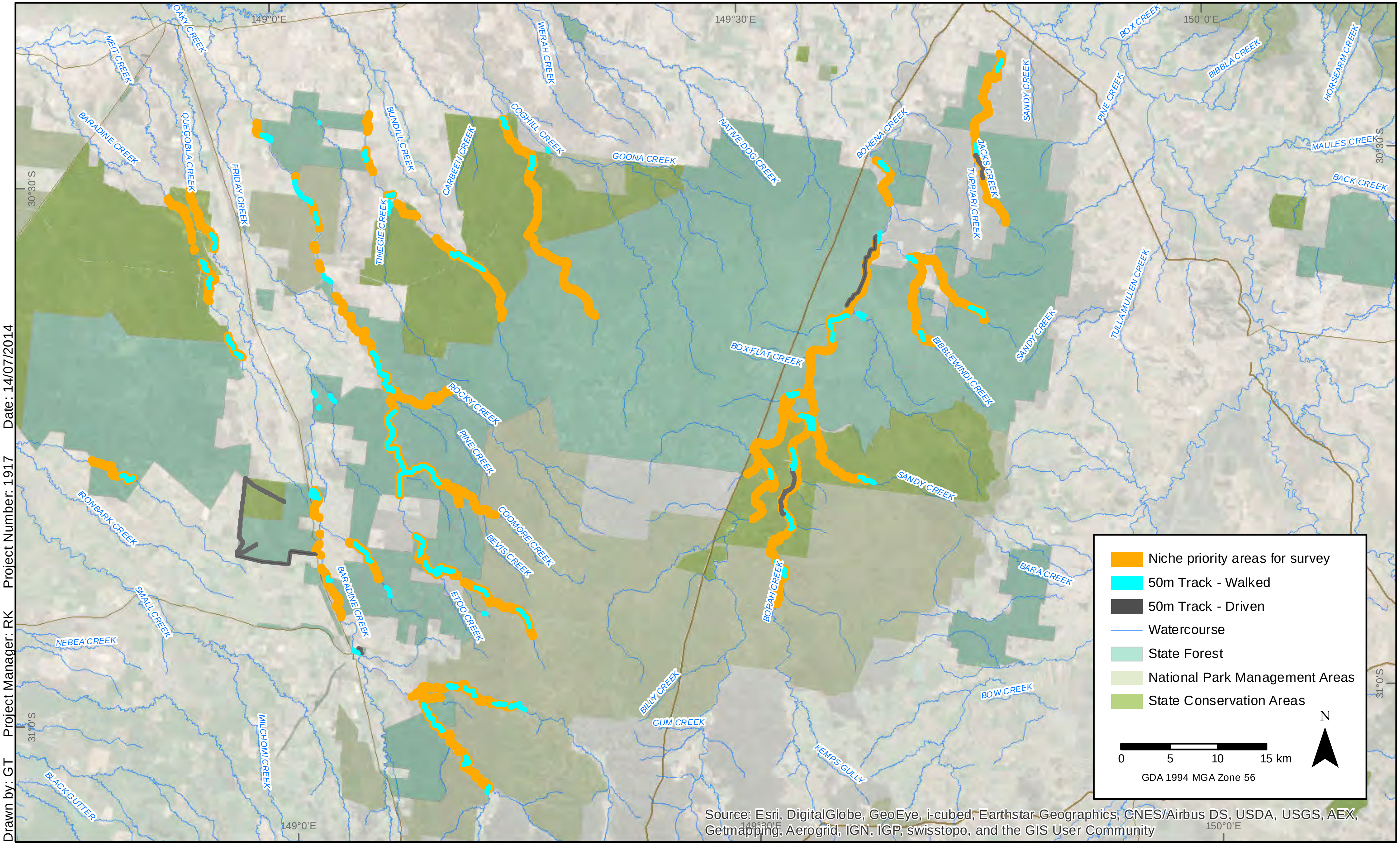
Project 1917: Koala refuges in the Pilliga

FIGURE 2

niche Environment and Heritage

Path: T:\spatial\projects\a1900\a1917_PilligaKoala\Maps\t\1917_Figure_2_ProposedSurveyAreas.mxd

Drawn by: GT Project Manager: RK Project Number: 1917 Date: 14/07/2014



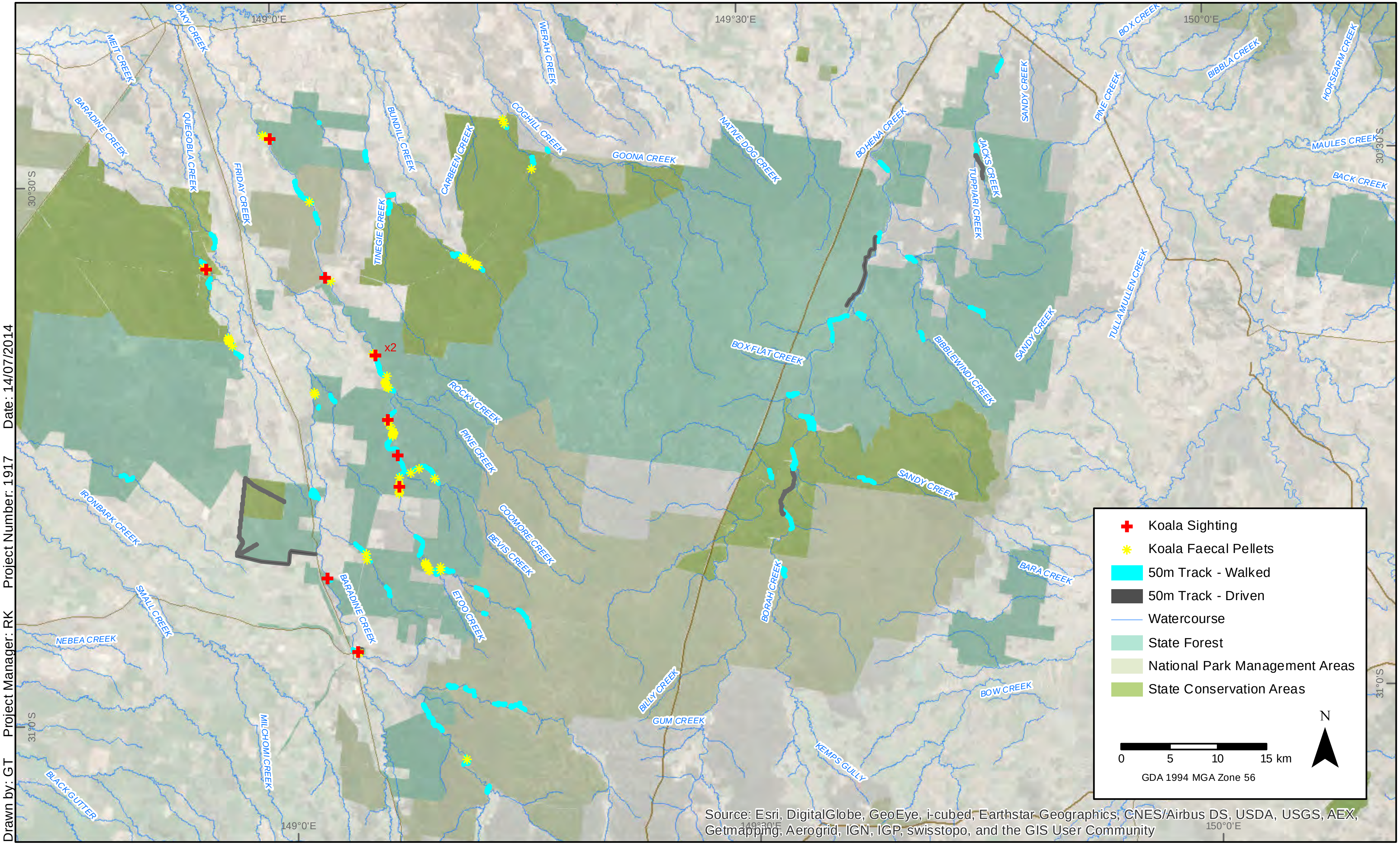
Priority, and actual, areas surveyed for koalas in April/May 2014

Project 1917: Koala refuges in the Pilliga

FIGURE 3

niche Environment and Heritage

Path: T:\spatial\projects\a1900\a1917_PilligaKoala\Maps\1917_Figure_3_Koala_SurveyAreas.mxd



Drawn by: GT Project Manager: RK Project Number: 1917 Date: 14/07/2014

Koala and koala faecal pellet records plotted over searched areas April/May 2014

Project 1917: Koala refuges in the Pilliga

FIGURE 4

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Path: T:\spatial\projects\a1900\a1917_PilligaKoala\Maps\1917_Figure_4_Koala Records.mxd

3 RESULTS

3.1 Search area

Over 1654 ha were searched on foot covering 112 km of red gum dominated creek line. An additional 17 km of roads in the vicinity of creek lines were driven and spot-lit. Away from creek lines, 25 km of roads were driven and spot-lit.

Despite some rainfall during autumn, the forest areas searched were still showing the signs of significant water stress (i.e. many trees were heavily defoliated or showed recent epicormic growth), almost certainly resulting from the severe rainfall deficit over spring and summer and the lack of any significant wet periods since March 2012 (BOM accessed April 2014). Normally permanent waterholes were dry during the 2013/14 summer, and even after the 2014 autumn rains many contained no standing water. While we have no measures of the subsurface water flows in sand filled creeks, water stress on many trees that utilise this water source was readily apparent through low levels of leaf coverage and dead outer branches.

3.2 Koala distribution

Ten koalas were directly observed during the study, occurring exclusively along Etoo (n=7) and Baradine Creeks (n=3). In addition, we found 81 faecal pellet sites (trees), many of which were clumped, that were primarily located along Etoo and Baradine Creeks or their immediate tributaries. Other creeks with koala pellet scats included Talluba Creek and Rocky Creek (off Coghill Creek). Table 1 presents an overview of the results by creek. Koala records are presented in Appendix 1 and mapped on Figure 4.

The koala and koala faecal pellet records were mapped into approximately 20 areas known to contain koalas. One of these areas contained a minimum of two koalas (a male and female). All other koala records were of single animals without any indication of another koala nearby. Even on the creek lines known to have koalas there were notable gaps in koala sign.

No koala faecal pellets were recorded along the creeks to the east of the Newell Highway although there are other recent records from this area. These include in Cocaboy No.2 Dam (M. Murphy, 2014, personal communication), Borah Creek near Kerringle Road (D. Paull, 2013, personal communication) and Sandy Creek near Delwood Road (M. Stanton, 2012, personal observation). No koala records were made by spotlighting from a vehicle at any of the areas surveyed.

The greatest density of koala records occurred in areas where the stream bed was 80 metres or wider. In streams where koalas were present there was a notable reduction in signs of koalas higher up the tributaries.

3.3 Koala micro-habitat

Red gums were the main tree species group that koalas were seen in (n=9). One koala was seen in a White Cypress Pine. A similar proportion of faecal pellet records were made under red gums and White Cypress Pine.

“Koala activity” was low at most sites where evidence of this species was detected. Koala faecal pellets were usually recorded under few trees. In some cases pellets were in high numbers (>100) indicating a strong preference being shown for particular individual trees. Evidence of koala-induced defoliation was uncommon but was seen at some sites.

Some sites showed strong evidence of past catastrophic wildfire, either from 2006/7 or 1997. These areas showed either eucalypts that had been directly killed by the fire or that had died post fire. The regeneration in these areas was immature, averaging only a few metres in height. These sites showed no evidence of koala occupation.

We found no strong evidence of higher koala concentrations near open water sources. Only two of the ten observed koalas were within 500 metres of a permanent water body. Of three waterholes that we inspected along Etoo Creek (Junction Waterholes, Euligal Crossing and Etoo Crossing), none of them had any signs of koala habitation within 400 metres.

Rather, the pattern of koala distribution was consistent with a low population density.

3.4 Koala behaviour and health observations

While not always easy to determine a koala’s behaviour, some were clearly seen accessing browse in red gums (n=3) or were obviously in a secure resting location (n=2) including one koala using a white cypress pine. One koala was seen accessing mistletoe growing in a river red gum.

Detailed health checks were not possible during this study. One koala near the Junction Waterholes (Etoo Creek) was observed to have a possible eye infection. At least one other koala appeared to have wet bottom, a symptom known to be associated with chlamydia infection. All koalas appeared to be in good muscular condition without signs of wasting, dehydration or food deprivation.

Samples of koala faecal pellets have been retained for potential future use. Uses may include diet examination, bacterial infection detection (particularly *Chlamydophila pecorum*/*Chlamydophila pneumoniae*) and genetic diversity.

No young or sub-adult koalas were observed. None of the koalas appeared to be displaying symptoms of old age.

There was a complete absence of koala remains present along our survey areas while skeletal material of other forest fauna was commonly encountered. This may indicate that koalas have not been dying near these refuge areas. However, it is more likely to indicate that the population decline occurred well before the current surveys, long enough to allow the robust skulls and jaws of koalas to be broken down by scavengers and weathering.

Table 1. Koala records by creek with area and creek length searched as a measure of effort. N indicates the number of search events associated with each creek. * Yearinan creek is sometimes called Baradine or Wittenbra Creek. Other creek names also vary. Locations are only an indication of the area that a creek occupies in the forest.

Creek	N	Latitude	Longitude	Hectares searched	Creek length(m) in search	Koala sightings	Additional koala faecal pellet sites
Etoo	17	-30.65	149.08	384	23257	7	36
Baradine	8	-30.80	149.04	147	8609	3	17
Merriwee	4	-30.63	148.94	54	3882		9
Talluba	6	-30.53	149.15	113	7724		8
Rocky (Nth)	3	-30.48	149.27	36	3160		3
Coomore	3	-30.77	149.15	65	5683		3
Coolangla	3	-30.86	149.09	45	4126		2
Gibbican	4	-30.89	149.22	86	7505		2
Yearinan*	6	-31.02	149.16	124	8546		1
Dinby	1	-30.77	148.82	20	1807		
Quegobla	1	-30.56	148.93	22	1427		
Cumbil Forest	2	-30.71	149.05	14	1162		
Middle	1	-30.45	149.05	2	72		
Tinegie	1	-30.52	149.12	19	1436		
Dandry	4	-30.99	149.21	91	5244		
Bark Hut	1	-30.91	149.21	5	365		
Yaminba	1	-30.79	149.52	16	870		
Borah	5	-30.80	149.55	146	9661		
Sandy	2	-30.78	149.60	36	3313		
Bohena	4	-30.60	149.61	104	5410		
Cowallah	3	-30.65	149.62	30	2410		
Bibblewindi	2	-30.63	149.69	34	2353		
Yellow Spring	1	-30.65	149.76	28	1878		
Jacks	2	-30.45	149.77	31	2635		
Total	85			1654	112534	10	81

4 DISCUSSION

4.1 Comparison with previous studies

The results of this study indicate a low population of koalas within the Pilliga Forests. Due to the low number counted (n=10), it is not possible to estimate the size of the current Pilliga koala population although it is likely to be, at best, only several hundred animals.

Historically, the Pilliga forests have had a koala population of variable density. Population trends appear to have fluctuated from common in the late 1800's to sparse after 1930, then increasing from the early 1980s until the late 1990s (van Kempen 1997, Kavanagh and Barrott 2001). However, it was not until recent decades that repeatable research methods provided a strong measure of koala abundance.

In 1993-1994, Date and Paull (2000) conducted a general wildlife survey throughout the Pilliga forests using a range of techniques applied at each of 90 transects, each 200 m in length. They reported evidence of koala presence (mainly from observations of faecal pellets) at 40 of 90 transects (44.4%). Koalas were recorded at 10 of 18 transects in Central Pilliga (56%), at 19 of 42 transects in East Pilliga (45%), at 7 of 18 transects in West Pilliga (39%) and at 4 of 12 transects in the Southern Pilliga (33%).

In comparison, Barrott (1999) recorded evidence of koala presence at 27 of 34 sites in Central Pilliga (79.4%), at 3 of 30 sites in East Pilliga (10.0%), and at 23 of 32 sites in West Pilliga (71.9%). She observed koalas directly, either by visual or aural confirmation, at a total of 41 sites, and indirectly, by observation of faecal pellets only, at a further 12 sites. This resulted in koalas being recorded at a total of 53 (55.2%) of the 96 sites surveyed (after one visit to each site). Koala pellets were observed at 32 sites (33.3%) after one visit. Further details are provided in Kavanagh and Barrott (2001).

Barrott (1999) found that Koalas had a generally broad distribution in the Pilliga forests. However, they were found only in limited numbers in the East Pilliga forests (recorded on three sites only, twice as incidental records), in part due to the frequent, severe fires that have occurred in the East. Koalas were recorded most frequently using Pilliga Box (*Eucalyptus pilligaensis*) - White Cypress Pine (*Callitris glaucophylla*) – red gum (mostly *E. blakelyi* and/or *E. chloroclada*) forests along creek lines, with Poplar Box (*E. populnea*) – White Cypress Pine also being highly utilised. Koalas were also recorded frequently in the White Cypress Pine – Narrow-leaved Ironbark (*E. crebra*) – Bull Oak (*Allocasuarina luehmannii*) forest type which had previously been considered by the Australian Koala Foundation (unpublished maps provided to State Forests of NSW) in their habitat model as being of only marginal habitat quality. Overall, the differentiation between "high" and "low" quality habitat for koalas, as defined and mapped by AKF, was not strongly supported by Barrott (1999).

Kavanagh and Barrott-Brown (2014) resurveyed the 96 sites originally surveyed by Barrott (1999). They recorded evidence of the koala (i.e. direct observation at one site, pellets at the remainder) at 10 sites, being 6 of 34 sites in Central Pilliga (17.6%), at 1 of 30 sites in East Pilliga (3.3%), and at 3 of 32 sites in West Pilliga (9.4%).

While the current study did not undertake standard SAT plots (i.e. where searches occur under 30 trees at each sampling location), pellets were recorded very infrequently at only

91 locations in approximately 1654 ha searched (over 112 km of creek line searched). Given that the red gum lined creeks have previously been identified as the primary habitat for koalas in the Pilliga, this suggests a significant decline in the abundance of the koala in the Pilliga since the study by Barrott (1999). Compared with the studies of Barrott (1999) and Date and Paull (2000), it appears that a significant and relatively rapid (i.e. within two generations) decline has occurred within the Pilliga koala population.

4.2 Possible causes of koala population decline

It is likely that the population of more than 15,000 animals estimated in 1998-1999 was close to the maximum known for these forests since European settlement (Kavanagh and Barrott 2001). Thereafter, the severe and prolonged millennium drought, together with the western extension of the 2006 wildfire into previously long-unburnt forests of the Central Pilliga, may have been the main causes for the recent marked decline in koala numbers throughout the Pilliga. The drought may have rendered much of the forest to sub-optimal koala habitat and the high population density may have contributed to a population ‘crash’ as has occurred elsewhere in Australia (Masters *et al*. 2004).

Koala populations are well known to be sensitive to drought and to extended periods of hot weather (Gordon *et al*. 1988, Seabrook *et al*. 2011, Lunney *et al*. 2012) and koalas often take extraordinary measures to avoid direct sunlight on hot, dry days (Kavanagh *et al*. 2007, Ellis *et al*. 2010). There were 2-3 “wet” years immediately following the drought but the results show that there was no apparent increase in koala population numbers. The distribution of the species remains restricted to relatively few locations in the Pilliga. The record high temperatures and low rainfall over the past 18 months appear to have placed a cap on any potential recovery. As no koalas with ‘back young’ were observed, it is possible that the population may still be declining.

In the late 1990s, koalas were widely distributed across the Pilliga landscape, utilising many different forest types (Barrott 1999, Date and Paull 2000, Kavanagh *et al*. 2007). At that time, Red Gums (mainly *E. blakelyi* and/or *E. chloroclada*) and Pilliga Box (*E. pilligaensis*) were the preferred food tree species of the koala, and White Cypress Pine (*Callitris glaucophylla*) and Rough-barked Apple (*Angophora floribunda*) were used extensively for diurnal shelter (Kavanagh *et al*. 2007). Now, in 2014, these tree species continue to provide important habitat for the koala and may also be an important component of koala refuge areas.

The climate change hypothesis, while compelling, takes no account of the unknown additive or alternative impacts on koala populations that might be expected to follow a population boom, including increasing predation by introduced predators and increasing impacts of disease. The recent intensification of forestry practices in the Pilliga may have incrementally contributed to this decline, although this is unlikely to be the key driver given that large areas (over 200,000 ha) of the Pilliga now occur in areas managed for nature conservation.

4.3 Information requirements

Further information is required before we can conclude the causes of the koala population decline. The information required relates to disease, accurate climatic and hydrological models, tree response to stress in the Pilliga environment and quantification of changes in forest management since the changes in tenure around 2004.

Altered leaf chemistry as a result of growing conditions and plant stress has been shown to potentially increase the concentration of leaf anti-nutrients and to decrease the concentration of nitrogen (Moore *et al.* 2004). These findings need to be quantified for the Pilliga forest context before we can determine if it has been a major driver of koala population decline.

There is long-term precipitation and temperature data available from weather stations around the Pilliga. Unfortunately, some of those stations have recently closed or have become inconsistent in their collection regimen. The data require careful screening and could produce useful drought indices for comparison with koala population data.

We have collected scat samples that may enable a number of analyses to be completed. These include:

- an analysis of the chlamydia status of the koalas surveyed in this study. This could be compared with baseline data collected in 1997/98 and reported in Kavanagh *et al.* (2007).
- an analysis of the diet of Koalas.
- Analysis of the genetic diversity of koalas, including diversity within the immune system (i.e. MHC genes) and estimate of the number of animals considered to occur based on mtRNA analyses.
- Analysis of stress levels (i.e. faecal cortisols) within koala scats and comparison with other stable populations from elsewhere.

4.4 Management implications

The current field survey does not allow for an estimate of the population of the current Pilliga koala population. However, this study does support the contention that the population has been dramatically reduced and may be at risk of extinction within several generations. The most resilient areas of habitat for the koala appear to be along the two main drainage lines surveyed (i.e. Etoo Creek and Baradine Creek). A third major drainage system, Borah Creek/Bohena Creek, appears to support very few animals at this time.

The riparian forest communities targeted for survey in this study did provide current habitat for the koala, and this contrasts with the paucity of records experienced recently from non-riparian areas (Kavanagh and Barrott 2014). The capacity of riparian areas to support significant relict populations appears to have been compromised by long, cumulative sequences of very hot days and the absence of any free water at most locations searched.

The hypothesis that permanent waterholes are essential for koala population survival and recovery following drought could not be tested rigorously because the autumn 2014 rains replenished some dry waterholes immediately before the surveys were conducted. It is likely, however, that the restricted availability of water during most of the last two droughts had already made its impact on the Koala population. Re-creating "chains-of-ponds" (Hesse and Humphreys 2001) and other permanent waterholes in strategic riparian areas may be the only way to drought-proof koala habitat refuges in the Pilliga and to provide an important buffer against the advancing march of climate change in this semi-arid environment.

Controlling the extent and severity of wildfires is also likely to benefit koala conservation, but the frequency of prescribed burning required to achieve this objective could be counter-productive unless it is restricted to strategic areas of low-quality habitat. Pest control, particularly for dogs and tiger pear, are known to be important measures to protect koalas. Tiger Pear (*Opuntia aurantiaca*) is thought to be a major cause of koala mortality, particularly along parts of Etoo Creek where this plant is abundant (Kavanagh *et al*. 2007). Dogs, and probably foxes, are known to prey on koalas. These introduced predators are currently subject to control operations in the Pilliga but the effectiveness of these programs needs to be evaluated. Motor vehicle strikes are a potential threat but no systematic recording or database of mortalities appears to exist. The role of disease in the recent decline of the Pilliga koala population cannot be discounted; it is recommended that a number of animals be captured and tested to determine the current levels of disease in the population. The current level of genetic diversity in the population should also be assessed.

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We thank Ross Irvine (Forestry Corporation of NSW, Dubbo) for approving our Special Purposes Permit to undertake Research in State Forests and Jarod Dashwood (FCNSW, Baradine) for facilitating, and Warwick Bratby (FCNSW, Dubbo) for approving, our entry into parts of State Forest that were temporarily closed to public access. We also thank John Whittall (National Parks and Wildlife Service, Baradine) for his approval to conduct this project on lands managed by the Service and for his ongoing support of our research in the Pilliga.

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7 APPENDIX

Appendix 1. Location co-ordinates of koalas and their sign in April/May 2014 at creek sites in the Pilliga forests.

Creek	Record Type	Date/Time	Latitude	Longitude	Observer
Baradine	Koala faecal pellets	29/04/2014 23:07	-30.70018	149.03456	RPK/KL
Baradine	Koala faecal pellets	29/04/2014 23:20	-30.70018	149.03428	RPK/KL
Baradine	Koala faecal pellets	29/04/2014 23:27	-30.70167	149.03539	RPK/KL
Baradine	Koala sighting	02/05/2014 16:44	-30.58177	148.9229	MAS/NR
Baradine	Koala faecal pellets	02/05/2014 17:23	-30.57998	148.9203	MAS/NR
Baradine	Koala faecal pellets	02/05/2014 19:02	-30.58177	148.9231	MAS/NR
Baradine	Koala sighting	04/05/2014 23:50	-30.873246	149.041364	RPK/KL
Baradine	Koala faecal pellets	08/05/2014 14:47	-30.9431	149.07293	RPK/KL
Baradine	Koala faecal pellets	08/05/2014 20:26	-30.94324	149.07276	RPK/KL
Baradine	Koala sighting	08/05/2014 21:00	-30.94203	149.07169	RPK/KL
Coolangla	Koala faecal pellets	28/04/2014 21:36	-30.8512	149.0844	RPK/KL
Coolangla	Koala faecal pellets	28/04/2014 22:16	-30.85628	149.08496	RPK/KL
Coomore	Koala faecal pellets	29/04/2014 16:33	-30.7839	149.16108	CM/MD
Coomore	Koala faecal pellets	29/04/2014 16:41	-30.77382	149.14406	RPK/KL
Coomore	Koala faecal pellets	29/04/2014 17:15	-30.77744	149.1353	RPK/KL
Etoo	Koala faecal pellets	29/04/2014 15:45	-30.79589	149.122	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 15:56	-30.79452	149.1221	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 16:20	-30.79189	149.1224	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 16:24	-30.79146	149.1225	MAS/NR
Etoo	Koala sighting	29/04/2014 16:30	-30.79048	149.1225	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 16:49	-30.78956	149.122	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 16:54	-30.78901	149.1222	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 16:57	-30.78887	149.1222	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 17:03	-30.78777	149.1223	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 17:23	-30.78162	149.1224	MAS/NR
Etoo	Koala sighting	29/04/2014 18:13	-30.7608	149.1216	MAS/NR
Etoo	Koala faecal pellets	29/04/2014 22:34	-30.68705	149.1127	MAS/NR
Etoo	Koala faecal pellets	01/05/2014 16:05	-30.462303	148.994664	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 16:09	-30.462255	148.994597	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 16:12	-30.46225	148.9946	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 16:14	-30.46188	148.9942	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 17:01	-30.45927	148.98772	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 17:31	-30.45994	148.99193	RPK/KL
Etoo	Koala sighting	01/05/2014 19:14	-30.4623	148.9962	RPK/KL
Etoo	Koala faecal pellets	01/05/2014 19:51	-30.52228	149.0363	CM/MD
Etoo	Koala sighting	01/05/2014 22:45	-30.59379	149.05017	CM/MD

Creek	Record Type	Date/Time	Latitude	Longitude	Observer
Etoo	Koala faecal pellets	01/05/2014 23:09	-30.59691	149.05587	RPK/KL
Etoo	Koala faecal pellets	03/05/2014 15:45	-30.86847	149.1521	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 16:00	-30.86828	149.1514	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 16:37	-30.8664	149.15	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 16:55	-30.86551	149.1493	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 17:27	-30.86357	149.148	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 17:39	-30.86264	149.1478	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 17:46	-30.86236	149.1476	MAS/NR
Etoo	Koala faecal pellets	03/05/2014 17:56	-30.86185	149.1477	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 15:40	-30.74195	149.11706	CM/MD
Etoo	Koala faecal pellets	08/05/2014 15:47	-30.74131	149.11731	CM/MD
Etoo	Koala faecal pellets	08/05/2014 15:54	-30.74112	149.11746	CM/MD
Etoo	Koala faecal pellets	08/05/2014 15:54	-30.74095	149.11746	CM/MD
Etoo	Koala faecal pellets	08/05/2014 15:55	-30.69753	149.1143	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 16:00	-30.74053	149.11758	CM/MD
Etoo	Koala faecal pellets	08/05/2014 16:06	-30.7404	149.11811	CM/MD
Etoo	Koala faecal pellets	08/05/2014 16:13	-30.7395	149.11755	CM/MD
Etoo	Koala faecal pellets	08/05/2014 16:22	-30.69681	149.113	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 16:32	-30.73574	149.11644	CM/MD
Etoo	Koala faecal pellets	08/05/2014 16:33	-30.69656	149.1123	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 16:45	-30.73182	149.11398	CM/MD
Etoo	Koala faecal pellets	08/05/2014 16:55	-30.69401	149.1111	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 16:57	-30.72845	149.11224	CM/MD
Etoo	Koala faecal pellets	08/05/2014 17:01	-30.72804	149.11198	CM/MD
Etoo	Koala sighting	08/05/2014 17:03	-30.72763	149.1121	CM/MD
Etoo	Koala faecal pellets	08/05/2014 17:12	-30.69267	149.1107	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 17:23	-30.69217	149.1114	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 22:17	-30.66588	149.0988	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 22:58	-30.66611	149.1004	MAS/NR
Etoo	Koala faecal pellets	08/05/2014 23:08	-30.6662	149.1008	MAS/NR
Etoo	Koala sighting	08/05/2014 23:23	-30.66743	149.1013	MAS/NR
Etoo	Koala sighting	08/05/2014 23:31	-30.66748	149.1012	MAS/NR
Gibbican/Etoo	Koala faecal pellets	03/05/2014 15:47	-30.86926	149.16351	CM/MD
Gibbican/Etoo	Koala faecal pellets	03/05/2014 16:08	-30.86626	149.16372	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 15:57	-30.64952	148.94492	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:08	-30.64827	148.94447	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:12	-30.64786	148.94474	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:15	-30.64765	148.9444	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:23	-30.6461	148.94378	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:28	-30.64767	148.94421	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 16:30	-30.64798	148.94423	CM/MD

Creek	Record Type	Date/Time	Latitude	Longitude	Observer
Merriwee	Koala faecal pellets	02/05/2014 16:34	-30.64839	148.94389	CM/MD
Merriwee	Koala faecal pellets	02/05/2014 17:01	-30.65403	148.9483	CM/MD
Rocky (Nth)	Koala faecal pellets	04/05/2014 21:49	-30.49887	149.27554	CM/MD
Rocky (Nth)	Koala faecal pellets	04/05/2014 22:53	-30.4553	149.248	MAS/NR
Rocky (Nth)	Koala faecal pellets	04/05/2014 23:20	-30.45137	149.2466	MAS/NR
Talluba	Koala faecal pellets	04/05/2014 16:02	-30.58151	149.20411	CM/MD
Talluba	Koala faecal pellets	04/05/2014 16:30	-30.58452	149.20896	CM/MD
Talluba	Koala faecal pellets	04/05/2014 16:43	-30.58599	149.21153	CM/MD
Talluba	Koala faecal pellets	04/05/2014 16:51	-30.57926	149.1995	MAS/NR
Talluba	Koala faecal pellets	04/05/2014 16:53	-30.58603	149.21277	CM/MD
Talluba	Koala faecal pellets	04/05/2014 17:01	-30.57922	149.1993	MAS/NR
Talluba	Koala faecal pellets	04/05/2014 17:05	-30.58708	149.21498	CM/MD
Talluba	Koala faecal pellets	04/05/2014 17:21	-30.57874	149.1989	MAS/NR
Yearinan*	Koala faecal pellets	30/04/2014 16:35	-31.04566	149.1855	MAS/NR

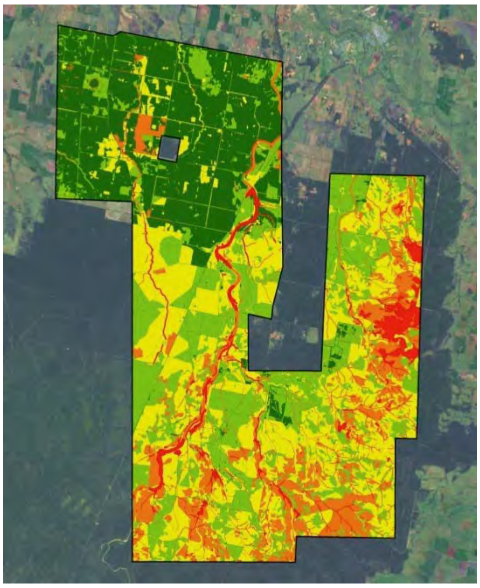
F8: Ecological sensitivity analysis

Narrabri Gas Project

Ecological Sensitivity Analysis

Prepared for
Santos NSW (Eastern) Pty Ltd

October 2015



This report should be cited as 'Eco Logical Australia 2015. *Narrabri Gas Project - Ecological Sensitivity Analysis*. Prepared for Santos NSW (Eastern) Pty Ltd.'

Contents

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Abbreviations

Abbreviation	Description
EEC	Endangered Ecological Community
ELA	Eco Logical Australia Pty Ltd
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
OEH	NSW Office of Environment and Heritage, formerly DECCW
TSC Act	*Threatened Species Conservation Act 1995*
WM Act	*NSW Water Management Act 2000*

1 Background

The potential constraints of the Narrabri Gas Project from an ecological perspective are complex and involve a number of unique ecological components including threatened flora, threatened fauna habitat, Endangered Ecological Communities, high quality vegetation, regional vegetation significance and large patch size. To present these constraints in a meaningful manner, an Ecological Sensitivity Analysis was undertaken for the project.

The Ecological Sensitivity Analysis was designed to identify the degree of ecological sensitivity, and hence potential constraint to development. The primary purpose of the Ecological Sensitivity Analysis is to inform the selection of locations for gas wells and associated infrastructure to maximise avoidance on areas of higher ecological sensitivity.

2 Methods

The Ecological Sensitivity Analysis used available spatial data as well as data collected through field investigations to develop initial ecological sensitivity. Criteria and weightings for available data were specifically developed for the process. The Ecological Sensitivity Analysis process included the following steps:

1) Data audit and selection
2) Decision criteria
3) Data preparation and weighting
4) Spatial sensitivity analysis.

This broad 4-step process has used an accepted spatial analysis methodology defined in GIS literature such as Burrough and McDonnell (1998) or Berry & Keck (2009) to identify and combine a number of variables to establish a spatially related ranking or prioritisation of values in an area.

2.1 DATA AUDIT AND SELECTION

A data audit was carried out on the available base information. This audit identified the suitability of each data set with regards to its resolution and accuracy, and also identified where modification was required, or if the data was suitable for use in the analysis.

Base data identified for audit included:

- Base imagery
- Light Detection and Ranging derived contours
- Mitchell landscapes (DECC 2008)
- Land ownership
- Road and track clearance areas*^
- Drainage (Digital elevation model and Contour data derived from Light Detection and Ranging data)*
- Flora and fauna records (State Forests 2011, ELA 2015)
- Vegetation mapping (ELA in 2015) and percentage cleared within bioregion (BioMetric; DECCW 2008)*^
- Field survey data – biometric condition, recorded threatened flora and fauna sightings, modelled flora and fauna habitat values (ELA in prep)*^.

* base data used for analysis
^ data modified/updated for analysis

Of the data sets identified for audit above, the following subset, including rationale for use, were identified for use as part of the analysis.

Base imagery	
Description	ALOS 3 band enhanced natural colour mosaic 10m resolution satellite imagery saved as an ECW file
Source	Commissioned by Eastern Star Gas; archived imagery from November 2006 (west) and March 2007 (east) mosaicked and orthorectified by Geoimage Pty Ltd
Usage	Context data for mapping and desktop image interpretation for checking derived drainage lines and top of bank for Bohena Creek
Rationale	Best available resolution consistent imagery
Light Detection and Ranging Contours	
Description	Vector line features of 0.25m contour lines across the study area
Source	Commissioned by Santos; derived from Light Detection and Ranging data collected via Airborne Laser Scanning (ALS) by AAM in 2014
Usage	This data set was used for the derivation of drainage centrelines and top of bank mapping
Rationale	Best available data
Road, track and infrastructure clearance areas	
Description	Polygon feature derived during vegetation mapping for the study area defining areas of clearance for significant roads and tracks and infrastructure development
Source	Desktop vegetation mapping by ELA (November 2013-February 2014)
Usage	1. Contiguous vegetation patch – all mapped roads and tracks were considered to form a barrier to contiguous extant vegetation 2. Roads, tracks and areas of infrastructure clearance omitted from analysis based on vegetation mapping including modelled species density and distribution, clearance in bioregion, vegetation biometric benchmark analysis,
Rationale	Tracks, roads and clearances are known to contribute to degradation of ecological values by acting as a disturbance barrier to habitat continuity as well as providing an access point for pest and weed species which may lead to increased disturbance and degradation within a patch of habitat and eventually fragmentation within a landscape; particularly for less mobile species. This dataset was collected specifically to provide an up to date representation of the current configuration of tracks, roads and clearances within the study area. Older datasets of tracks and roads were available from State Forests NSW; however, the correlation between tracks in the State Forests NSW dataset and actual tracks on the ground proved to be inconsistent from attempts at validation through desktop inspection of recent imagery as well as on ground validation.
Drainage Centerline	
Description	Vector Polyline features representing centrelines of watercourses within the study area.
Source	Base 1:50,000 data from NSW Digital Topographic Data base (NSW Land and Property Management Authority) updated by Eco Logical Australia (May – June 2014) at a scale of 1:15 000 by utilising high-resolution aerial imagery, elevation (1m) and contour (0.25m) data derived from Light Detection and Ranging.
Usage	This dataset was used for the riparian corridors decision criteria. Polyline features classified with Strahler stream order were used to identify the necessary vegetation riparian zone buffer under

	the NSW *Water Management Act 2000* (WM Act). As riparian corridors include the channel width, drainage lines not covered by top of bank mapping (see below) had an average channel width (determined through systematic review) applied based on their stream order. Thus the drainage centreline dataset was buffered according to the relevant riparian zone buffer required and the average channel width buffer for each stream order. A presence/absence score was used for the sensitivity analysis. Areas within mapped riparian corridors were allocated a score of 100.
Rationale	Drainage lines and associated riparian vegetation form the basis for habitat health and connectivity across a landscape. Field survey has shown that riparian vegetation in the study area has the greatest abundance of fauna habitat features.
Top of Bank	
Description	Vector polygon layer depicting the top of bank extent for larger channels such as Bohena Creek and all 5th and 6th order drainage lines within the study area.
Source	Derived by Eco Logical Australia through a desktop analysis of 0.25m contours (derived from Light Detection and Ranging) and high resolution (10cm) aerial imagery.
Usage	This dataset was used to support the buffered drainage decision criteria. To account for the need to include channel widths as part of the total riparian corridor width, top of bank was digitized for drainage lines with larger channels that could easily be identified at a scale of 1:15 000. (including all 5th and 6th order drainage lines). The areas identified within the top of bank mapping were buffered by the appropriate riparian zone buffer (based on their stream order and as triggered by the WM Act) and combined into the riparian zone corridor dataset. Areas within mapped riparian corridors were allocated a score of 100.
Rationale	Larger channels, such as Bohena Creek, contain significant habitat values. When examined through visual interpretation of the base imagery and contour data, the bed of these creeks can vary greatly in width across the study area. To account for the need to include channel widths as part of the total riparian corridor, top of bank was digitized for these areas to provide a more relevant representation of their extent for subsequent buffering of riparian zone.
Threatened Flora Records	
Description	Point locations denoting locations of Threatened Flora records/Threatened Flora surveys
Source	ELA 2013/2014
Usage	Used to define polygon areas of observed population occurrence for selected Flora species. Polygons were attributed with estimated species density based on survey observations. These densities/areas were then also used in conjunction with the study area vegetation mapping to determine an approximate density of species for given vegetation communities across the study area (in suitable vegetation types).
Rationale	Although not comprehensive across the study area, the data utilised provides the best available information on the recorded locations of threatened flora found within the study area.
Modelled Threatened Flora Occurrence (Vegetation Association)	
Description	Vegetation polygons from vegetation mapping attributed with the densities of threatened flora species modelled to occur within them
Source	ELA 2013/2014
Usage	Used to model the density and count of selected threatened flora species
Rationale	Although not comprehensive across the study area, the data utilised provides the best available

	information on the recorded locations of threatened flora found within the study area.
Vegetation mapping and percentage cleared within bioregion	
Description	Vector polygon layer defining the distribution of biometric vegetation types within the study area as well as associated % cleared within the bioregion (see Sections 2, 3 and 4 of this report).
Source	Vegetation mapping (November 2013-February 2014) and State Forest forest type mapping (State Forests 2007).
Usage	The finalised vegetation data set was used as a basis for the following decision criteria: 1. Endangered Ecological Communities –were given a score of 100 based on their state and federal legislative significance. 2. Vegetation conservation significance in the region – score is made up of the % of each vegetation community cleared within the Namoi Catchment Management Authority, based on pre1750 vegetation mapping. This score is attributed to each identified vegetation community (see Section 3.1.2 of this report). 3. Threatened Fauna Habitat Value – the scoring within this criteria is made up of the number of predicted fauna species likely to occur within each vegetation weighted by the nature of utilisation of given vegetation types by each species (Breeding (100), Foraging (50), Dispersal (10)), This score was then weighted by EPBC/TSC status and converted to an overall rating which was then normalised into an index between 0 and 100 (see Appendix A of this report). As some vegetation types provide more foraging/sheltering/breeding resources for fauna groups/species than others, this component identifies those vegetation types that support the greatest number of threatened fauna species, as well as those that support threatened species with high conservation significance. An additional criterion was added for the Pilliga Mouse as additional field based information and desktop modelling refined the dispersal, foraging and breeding areas of this species.
Rationale	The mapped distribution of vegetation types across the study area is a critical data set for use in the sensitivity analysis. This information provides the basis for biodiversity and significant habitat across the study area. The vegetation information has been derived into the distribution of biometric vegetation types in order to provide the most accurate representations of natural ecological associations across the study area.
Patch Size	
Description	Vector polygon layer defining the distribution of contiguous vegetation across the study area
Source	Desktop vegetation mapping (November 2013 - February 2014)
Usage	The distribution of vegetation types were consolidated into patches of contiguous vegetation separated by other patchs by mapped roads, tracks or other clearances. The score was made up of the overall size of each patch of contiguous vegetation normalised into a value between 0 and 100.
Rationale	The use of patch size as a criterion for determination of ecological sustainability of habitat or conservation significance is a generally well accepted principle (Drinnan 2005).

2.2 DECISION CRITERIA

A suite of decision criteria were defined to develop an ecological sensitivity analysis for the study area (**Table 1**). The criteria were identified through an internal workshop process (attended by ecologists and conservation planners) and based on key indicators of biodiversity values and available information. The following resultant decision criteria were based on major values for biodiversity and conservation.

Table 1: Biodiversity Conservation Values and Decision Criteria

Major Value	Decision Criteria	Indicator Data Set
Statutory/Conservation Value	Endangered Ecological Communities and locally significant communities	Vegetation Communities
	All identified threatened flora records	Field Survey Data
	Identified threatened fauna habitat (Pilliga mouse)	Vegetation Communities; Field Survey Data; Fauna databases
	Areas within 50m of drainage lines	Drainage
Landscape Conservation Value	Areas of rare vegetation within the region	Vegetation Communities and % cleared in the region
	Consolidated habitat	Vegetation Patch Size
Condition	Terrestrial Biodiversity	Vegetation Communities and Field Survey Data (Biometric Score)
	Areas of high quality vegetation / fauna habitat	Vegetation Communities; Field Survey Data; Fauna databases

2.3 DATA PREPARATION AND WEIGHTING

Based on the decision criteria (Step 2, **Table 1**), the required datasets were derived using the available base information (Section 5.1.1).

A process based on an Analytical Hierarchy Process (AHP) was adopted to rank and weight the identified criteria for the measurement and analysis of ecological sensitivity across the study area. The Analytical Hierarchy Process is a recognised multi-criteria analysis process which is suitable for complex decisions which involve the comparison of decision elements which can be difficult to quantify and ranks and prioritises values using decision analysis tools to summarise comparisons of the items importance (Saaty 1980; Crossman *et al.* 2009; Mendoza and Macoun 1999).

In this case the relative ranking and weighting for each of the resultant criteria datasets was assigned using Analytical Hierarchy Process methods via a Delphi based process (Linstone and Turoff 1975) in an internal workshop/group environment to achieve consensus among group participants. It involved the use of discussion and controlled feedback with statistical aggregation and consensus of the workshop participants where they had the opportunity to discuss what the criteria were measuring.

Generally, the criteria were ranked from 1 to 5 in order of ecological sensitivity to biodiversity conservation significance (5 being the highest). This was initially carried out individually, tallied, averaged and then collectively re-ranked through discussion. Following the ranking process each criteria was collectively assigned a multiplier for the resultant criteria score, which reflects the relative importance of the criteria ranking towards ecological sensitivity within the context of the study area and major values for biodiversity and conservation.

Table 2 broadly identifies the rationale for ranking and weighting as defined through group discussion. The rationale for rank and weight of each criterion is defined in **Table 3**.

Table 2: Summary of rank and weighting values

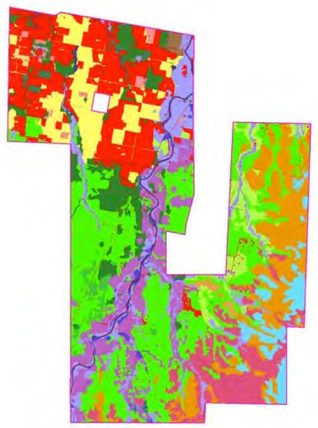
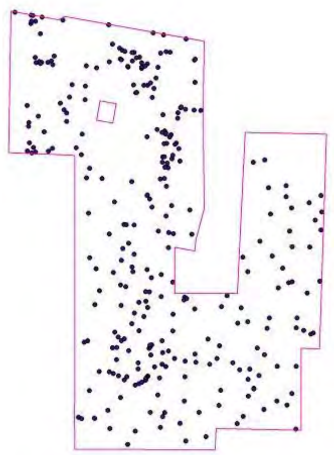
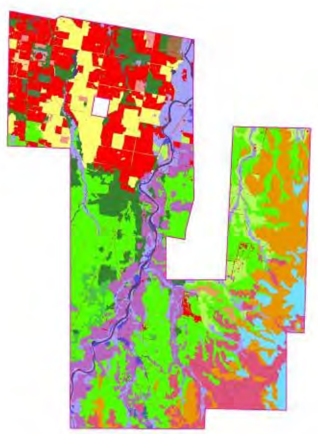
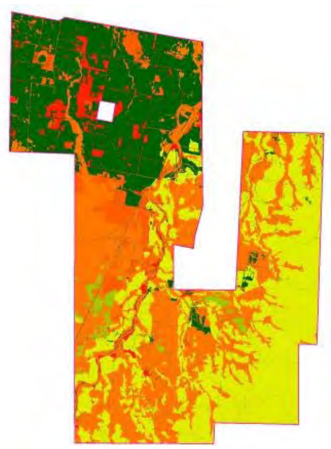
Rank	Assigned Weight	Rationale
5	x3 & x4	Values that are recognised as most important across the study area. These are associated with state or national significance for biodiversity conservation value, including those with legislative status or that are associated with state recognised key processes
4		
3	x2	Values that generally contribute to biodiversity conservation significance at the local and regional level
2		
1	x1	Values that support local biodiversity significance through consolidation of important habitat

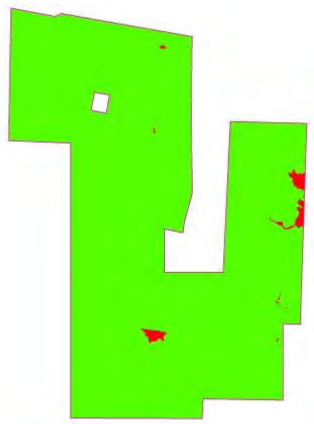
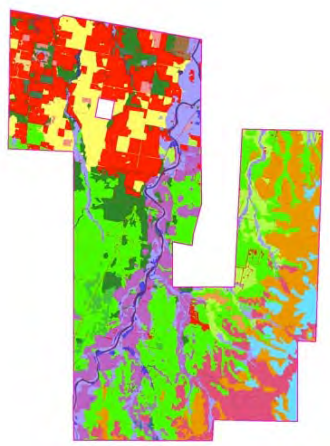
Table 3: Rationale for rank and weighting for each criterion.

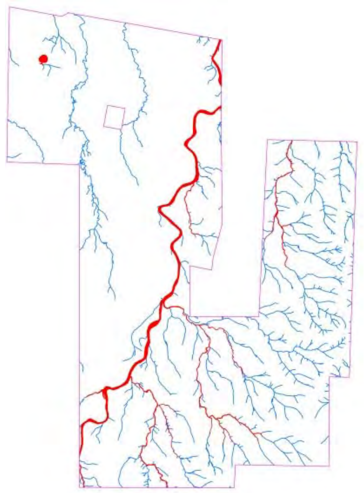
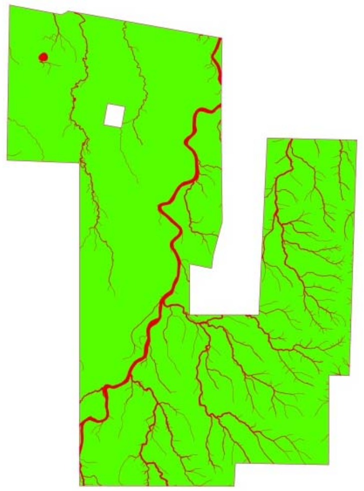
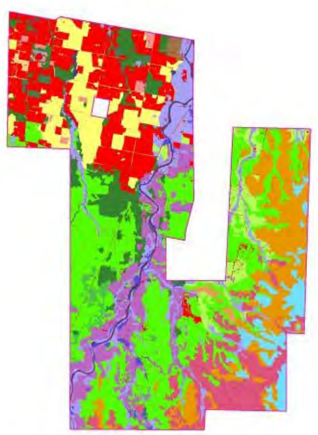
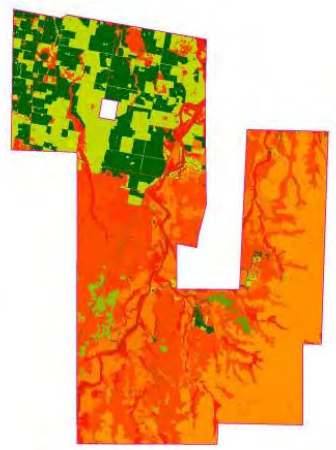
Decision Criteria	Rank	Weight	Rationale
Endangered Ecological Communities and locally significant communities	5	x3	These communities in the area include Fuzzy Box Woodland, Brigalow, Weeping Myall Woodlands and Carbeen Open Forest.
All identified/surveyed threatened flora records	5	x3	Threatened flora records identified through field survey all have a state legislative status under the TSC Act; including 5 species with national legislative status under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
Modelled distribution/density of threatened flora based on vegetation association	5	x3	Threatened Flora species modelled all have a state legislative status under the TSC Act including several with national legislative status under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
Areas of rare vegetation within the region	4	x3	Vegetation clearance contributes to loss of biodiversity as a state recognised key threatening process. This value reflects the importance for the conservation of each vegetation community.
Riparian corridors	4	x3	Drainage lines and associated riparian vegetation form the basis for habitat health and connectivity across a landscape. The importance of riparian corridors is consistent with state legislative guidelines and the NSW *Water Management Act 2000* (WM Act).
Terrestrial Biodiversity	4	x3	This value provides an indicator of biodiversity across the study area, but is directly related to a state-wide recognised measure
Areas of high quality fauna habitat	3	x2	This criterion identifies the overall contribution to values for fauna habitat specific to the regional context.
Identified habitat for Pilliga Mouse	5	x4	This criterion describes the habitat values of areas for the Pilliga Mouse life cycle including foraging and breeding.
Consolidated habitat	2	x2	This value identified local consolidation of biodiversity across the study area.

Table 4 provides a summary of the data prepared for the analysis and associated criteria, values used, and the defined rank and weightings developed for the analysis. All raster datasets were processed with a cell size of 10m to maximise the resolution of the raster representation of vector inputs whilst maintaining suitable file sizes and geoprocessing times.

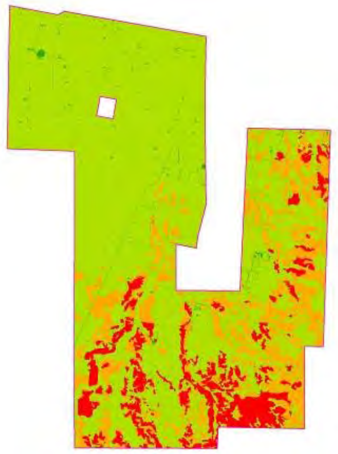
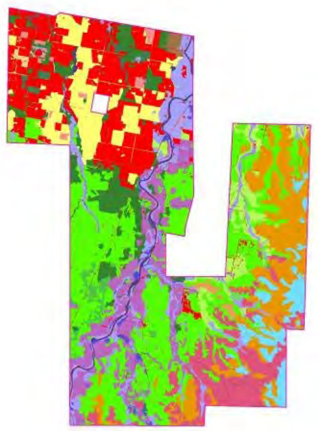
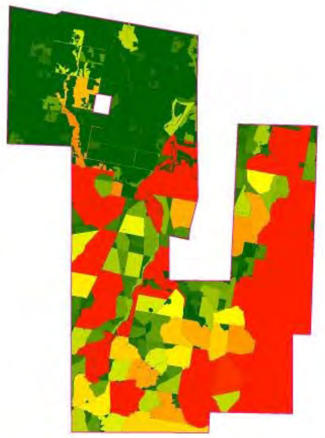
Table 4: Data preparation and weighting

Base Data	Derived Layer Name	Name as per decision criteria	Description	Criteria	Values	Rank	Weighting
Vegetation 	Endangered Ecological Community **[eec]** 	Endangered Ecological Communities and locally significant communities	Endangered Ecological Communities. Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions Myall Woodlands in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions Fuzzy Box Woodland on alluvial soils of the south western slopes, Darling Riverine Plains and Brigalow Belt South bioregions	All Endangered Ecological Communities	0 or 100. 0 = all non-Endangered Ecological Communities, 100 = Endangered Ecological Communities or significant community	5	x3
Field survey plots 	**Biometric score [BioMetric]** 	Terrestrial Biodiversity	A state-wide recognised measure (plot based) of terrestrial biodiversity, as applied to the identified broad-scale vegetation zones. Indicator for fauna habitat values.	Areas of high quality vegetation and fauna habitat	Normalised % biometric score 0 = lowest possible score, 100 = highest possible score Original Value range from 0 - 98	4	x3
Vegetation type 	**% Cleared in Bioregion [PC_clear]** 	Areas of rare vegetation within the region	The percentage of a particular vegetation community that has been cleared within the Namoi Catchment Management Authority since 1750 based on vegetation type.	Vegetation of conservation significance within the region	Normalised score from 0 to 100. 0 = lowest % cleared, 100 = highest % cleared Original Value range from 30-90	4	x3

Base Data	Derived Layer Name	Name as per decision criteria	Description	Criteria	Values	Rank	Weighting
Threatened flora (surveyed species) 	**Observed Threatened Flora [Threat_Flora]** 	All identified/surveyed threatened flora records	Mapped distribution of *Bertya opponens, Lepidium monoplocoides, Pommaderris queenslandica, Rulingia procumbens* and *Myriophyllum implicatum* based on targeted surveys in areas of known high density populations	Areas with verified high abundance of threatened flora species	0 or 100. 0 = outside indicative area of species occurrence 100 = within indicative area of species occurrence	5	x3
Vegetation (ELA 2013-2015) 	**Threatened Flora modelled distribution [Modelled_Flora]** 	Modelled distribution/density of threatened flora based on vegetation association	Classification of vegetated areas based on the likely occurrence of selected threatened flora species	Areas in which threatened flora species are predicted to occur	Normalised score from 0 to 100 based on the number of predicted threatened flora weighted by Flora TSC/EPBC status. 0 = no modelled species occurrence, 100 = highest modelled species occurrence (weighted by species status)	5	x3

<table>
<tr><th>Base Data</th><th>Derived Layer Name</th><th>Name as per decision criteria</th><th>Description</th><th>Criteria</th><th>Values</th><th>Rank</th><th>Weighting</th></tr>
<tr><td>Drainage
</td><td>Riparian Corridors [Riparian]
</td><td>Riparian corridors</td><td>Riparian corridors as per the specifications of the WM Act. Strahler stream order classification for every watercourse and associated top of bank / average channel width mapped. Riparian zone buffers were then applied to identify total riparian corridor widths under the WM Act:
<table>
<tr><th>Watercourse Strahler Stream Order</th><th>Riparian Zone (each side of watercourse)</th><th>Total Riparian Corridor Width</th></tr>
<tr><td>1st order stream</td><td>10 m</td><td>20 m + channel width</td></tr>
<tr><td>2nd order stream</td><td>20 m</td><td>40 m + channel width</td></tr>
<tr><td>3rd order stream</td><td>30 m</td><td>60 m + channel width</td></tr>
<tr><td>4th order or greater stream</td><td>40 m</td><td>80 m + channel width</td></tr>
</table></td><td>Riparian corridors as per the WM Act</td><td>0 or 100.
0 = not a riparian corridor,
100 = riparian corridor as per the WM Act.</td><td>4</td><td>x3</td></tr>
<tr><td>Field survey plots and vegetation type
</td><td>Threatened Fauna Habitat value [Fauna_hab]
</td><td>Areas of high quality fauna habitat</td><td>A measure of the suitability of a vegetation type to provide habitat for threatened fauna based on field assessment and vegetation type.
The predicted number of threatened fauna likely to occur in each vegetation type formed a matrix for identifying important fauna habitat. The majority of the study area is considered important habitat for different groups of threatened fauna species. Further details are found in Appendix A.</td><td>Areas of high quality vegetation / habitat</td><td>Normalised score from 0 to 100 based on the number of predicted threatened fauna and habitat utilisation
0 = lowest suitability,
100 = highest suitability

Original value range based on:
Dispersal – 10
Foraging – 50
Breeding - 100</td><td>3</td><td>x2</td></tr>
</table>

Base Data	Derived Layer Name	Name as per decision criteria	Description	Criteria	Values	Rank	Weighting
Pilliga mouse habitat 	**Threatened Fauna Habitat [thr_fauna_hab]** 	Identified habitat for Pilliga Mouse	Classification of vegetated areas into potential habitat value for the threatened Pilliga Mouse, from dispersal (lowest value), secondary and primary habitat (highest value).	Areas of important Pilliga mouse habitat	Dispersal (Rest of study area not classified as cleared) = 10 Secondary = 50 Primary = 100	5	x4
Vegetation (ELA 2013-2015) 	**Patch Size [Patch]** 	Consolidated habitat	The size of a patch of vegetation. A patch is defined as an area of consolidated vegetation that is separated from other patches by a mapped road or track or other areas cleared of vegetation.	Consolidated habitat	Normalised score from 0 to 100. 0 = smallest patch size, 100 = patch at least 1000ha in size Original Value range from <0.01ha – 6037ha	2	x2

2.4 SPATIAL SENSITIVITY ANALYSIS

The sensitivity analysis was carried out as a GIS analysis which combined all the spatial datasets into a single sensitivity dataset. A normalised score was derived for each criterion (between 0 and 100) to eliminate numerical bias in the calculation.

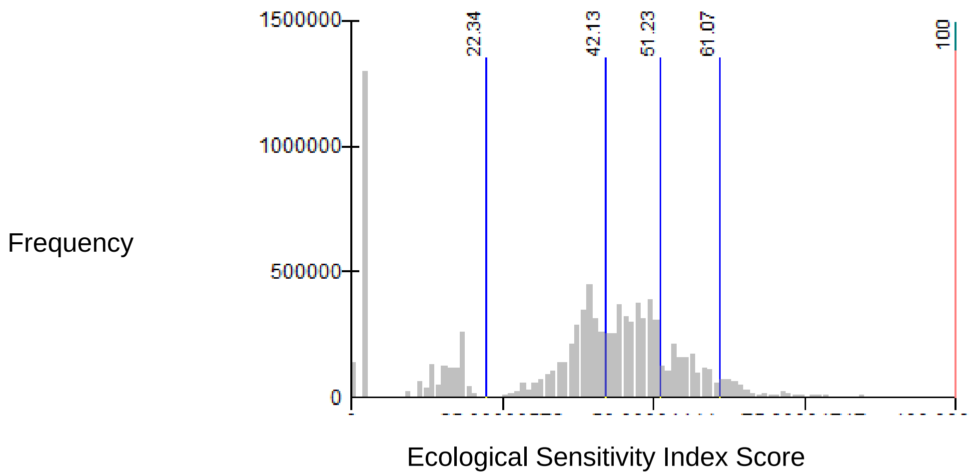
All scores for each dataset were spatially maintained as separate attributes within the derived dataset. The final part of the analysis combined all the scores from each derived layer and applied the weightings identified in the previous step to calculate a sensitivity index.

The values for each data set are added and multiplied by the assigned weighting to calculate a sensitivity score using the following equation:

Sensitivity Index = {(Patch*2) + (Fauna_hab*2) + (thr_fauna_hab*4) + (BioMetric*3) + (PC_clear*3) + (Riparian*3) + (Threat_Flora*3) + (Modelled_Flora*3) + (eec*3)}

The final score (from 0 – 1986) was then normalised to provide the sensitivity index value from 0-100.

The calculated index is then converted into four relative sensitivity classes based on identified trends (clustering) in the sensitivity index as shown in the graph below. The break points to define the five classes were identified using the natural breaks method at scores of 22.34, 42.13, 51.23 and 61.07.



The five sensitivity classes across the study area through the Ecological Sensitivity Analysis can be defined as:

- **Low (0 – 22.34)** – Areas that include a high degree of disturbance which impact on long term viability. Impacts should be directed to these areas wherever possible.
- **Low - Moderate (22.34 – 42.13)** – Areas that exhibit effects of disturbance, or habitat values which are of lower sensitivity in the regional context. Impacts on these areas should be minimised at the site scale.
- **Moderate (42.13 – 51.23)** – Areas that exhibit some effects of disturbance, or habitat values which are of moderate sensitivity in the regional context. Impacts on these areas should be minimised at the site scale.
- **Moderate - High (51.23 – 61.07)** – Areas that include a range of ecological values, including those listed under State or Federal legislation. Maximise avoidance on these areas.

- **High (>61.07) -** Areas which contain a combination of significant ecological values, including those listed under State or Federal legislation. Maximise avoidance on these areas.

Figure 1 summarises the analysis based on the criteria defined in step 2.

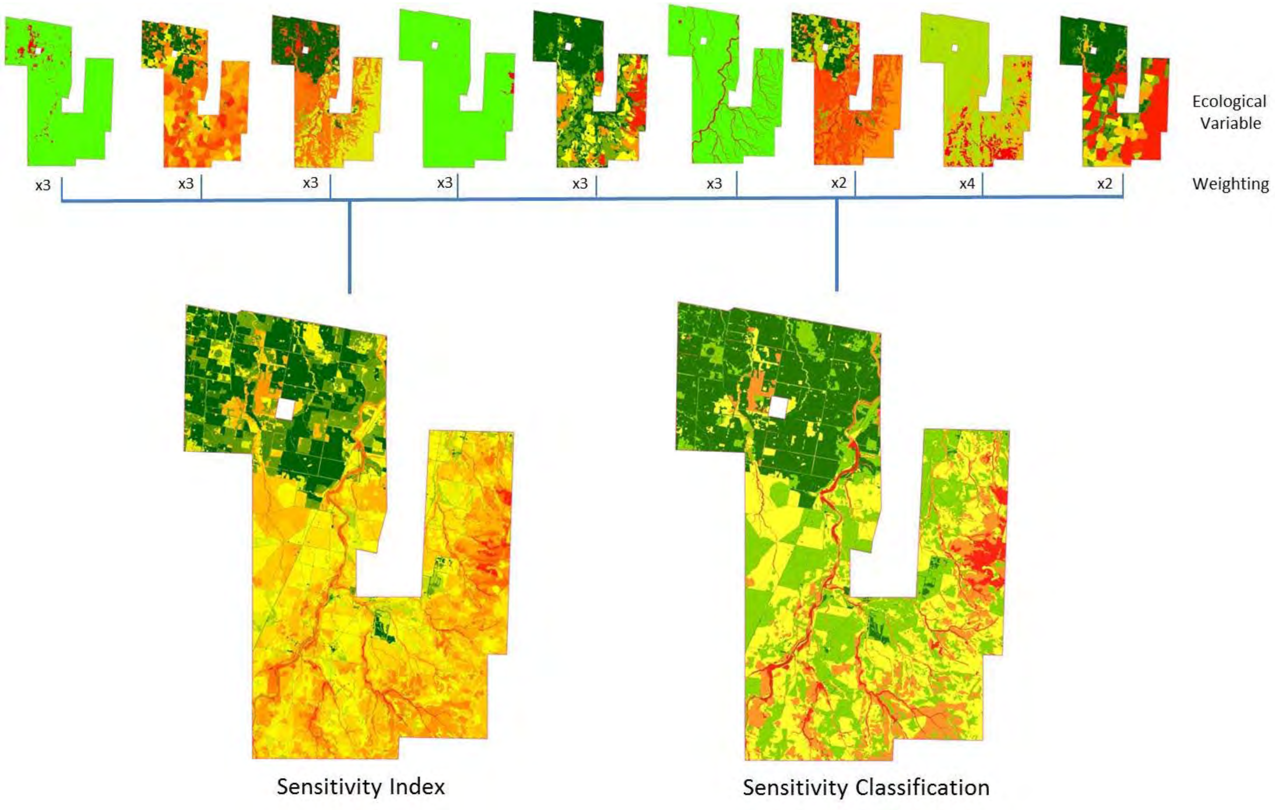


Figure 1: Derivation of ecological sensitivity

3 Results

A breakdown of the areas calculated under each ecological sensitivity class across the study area can be found in **Table 5**. The ecological sensitivity classes are mapped in **Figure 2**.

Table 5: Ecological sensitivity classes across the study area

Ecological Sensitivity	Area (ha)	% Area
Low	23,984	25%
Low - Moderate	26,009	27%
Moderate	28,481	30%
Moderate - High	12,620	13%
High	3,983	4%
Total	**95,077**	**100**

*It is noted that although the high resolution of the analysis (10m raster based) improves the accuracy of spatial statistics there must be allowance for a small degree of discrepancy in calculated areas due to the way linear features are represented in rasters. This is particularly with respect to the many narrow (<10m) tracks and trails in the study area.

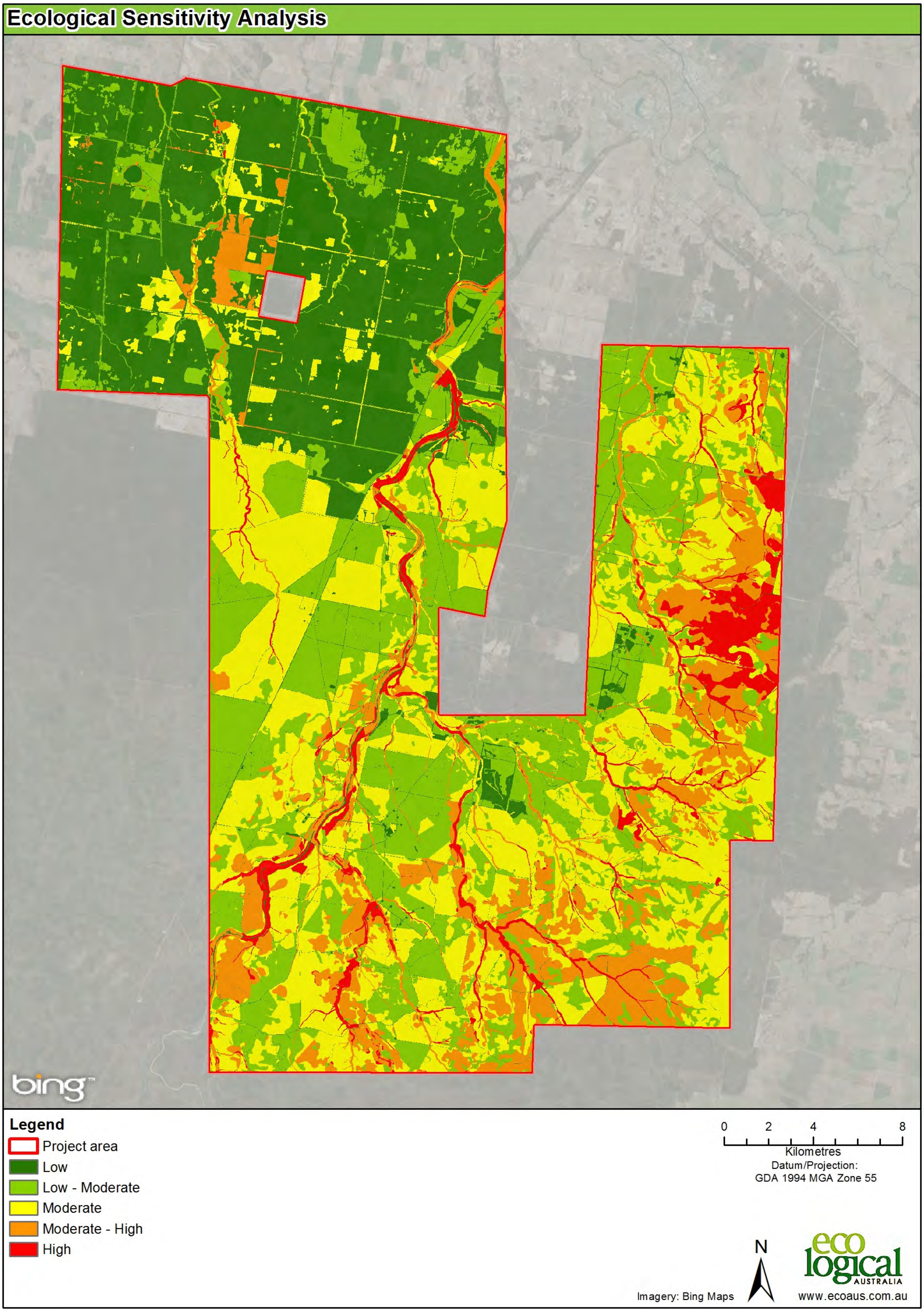


Figure 2: Ecological Sensitivity Analysis

4 Discussion

4.1 RECOMMENDATIONS FOR IMPLEMENTATION

The Ecological Sensitivity Analysis model has been developed to identify the degree of ecological sensitivity and providing a meaningful way to maximise the avoidance of impacts on areas of 'moderate-high' to 'high' ecological sensitivity.

Areas of 'moderate-high' to 'high' ecological sensitivity contain ecological values of state or federal significance, or a combination of values which have contributed to higher ecological sensitivity (e.g. close to drainage, threatened species presence and high % cleared in the bioregion). Due to the ecological sensitivity of these areas, it is recommended that the project maximises avoidance on these areas wherever possible.

Where there is potential to minimise ecological impacts through design alterations, it is recommended that infrastructure identified within 'high' or 'moderate - high' ecologically sensitive areas is relocated to adjoining areas of 'low - moderate' or 'low' ecological sensitivity wherever possible. Infrastructure identified within 'low - moderate' or 'low' ecological classes should seek to minimise impacts at the individual site scale (i.e. though micro-siting).

It is specifically noted that areas mapped as being 'low' or 'low - moderate' ecological sensitivity still contain sensitive ecological values (including threatened species), and impacts should still be minimised as much as practicable.

4.2 LIMITATIONS

The Ecological Sensitivity Analysis is based on the data available at the time of analysis. Changes to underlying data layers could change the outcomes. Third parties have provided a number of data layers, and thus limitations placed on the accuracy of that data would apply.

Changes to the methodology used to combine the data layers could result in some changes to the results; however this is not considered a significant as numerous iterations of the Ecological Sensitivity Analysis model were run and produced similar outcomes.

References

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Appendix A Derivation of Fauna Habitat Value Layer

A measure of the suitability of a vegetation community to provide habitat for threatened fauna based on field assessment and vegetation type was developed to contribute to the ecological sensitivity assessment.

The following process describes how the threatened fauna habitat value categories were calculated.

1. The likelihood of occurrence of each threatened species, identified through 50 km radius database searches around the study area and literature review, was determined per Plant Community/Biometric Vegetation type based on knowledge of each threatened fauna species' habitat requirements, and observations made of habitat elements present in vegetation types during field survey. Information in Namoi Catchment Management Authority Regional Vegetation Community technical report (ELA 2009) was used to assist in determining the likelihood of species occurrence within vegetation types. The Namoi Catchment Management Authority Regional Vegetation Community technical report (ELA 2009) lists threatened fauna species previously recorded in the Namoi Regional Vegetation Classes, which could be translated to equivalent Biometric vegetation types. The terms used in assigning a species' likelihood of occurrence were:
    - "yes" = the species was or has been observed in the study area
    - "likely" = a medium to high probability that a species uses the study area
    - "potential" = suitable habitat for a species occurs in the study area, but there is insufficient information to categorise the species as likely to occur, or unlikely to occur
    - "unlikely" = a very low to low probability that a species uses the study area
    - "no" = habitat in the study area and in the vicinity is unsuitable for the species.

1) The likelihood of a threatened species being impacted by the Narrabri Gas Project was determined. Five categories were used in assigning a species' likelihood of impact:

    - "no" = there is no risk that a species will be impacted. The species and its habitat are not present in the study area
    - "low" = there is a low risk that a species will be impacted given the availability of remaining potential habitat in the study area and the species' ecology and behaviour
    - "moderate" = there is a moderate risk that a species will be impacted given the availability of remaining potential habitat in the study area and the species' ecology, behaviour, and specific habitat requirements
    - "high" = there is a high risk that a species will be impacted given the availability of remaining potential habitat in the study area and the species' ecology, behaviour, and specific habitat requirements
    - "very high" = there is a very high risk that a species will be impacted given the availability of remaining potential habitat in the study area and the species' ecology, behaviour, and specific habitat requirements.

2. The risk that a threatened fauna species would be impacted by the proposal was determined based on its likelihood of occurrence in the study area and likelihood of being impacted by the proposal. The following matrix was used to calculate risk, with five categories of risk assigned.

		Likelihood of impact				
		No	Low	Moderate	High	Very High
Likelihood of occurrence	Yes	No risk	M	H	H	VH
	Likely	No risk	M	M	H	H
	Potential	No risk	L	M	M	H
	Unlikely	No risk	L	L	M	M
	No	No risk	No risk	No risk	No risk	No risk

3. The number of species with a low, moderate, high and very high risk of being impacted was tallied per vegetation type. Species with the same conservation significance status were tallied separately to those with different conservation significance statuses.

4. Multipliers were devised to assign a level of importance to species, reflecting their conservation significance under the EPBC Act and TSC Act. The multipliers were as follows:

Status	Multiplier
EPBC (Endangered)	4
EPBC (Vulnerable)	3
EPBC (Migratory)	1
TSC (Endangered)	3
TSC (Vulnerable)	2

5. Counts of species (step 4) were multiplied by the multipliers devised in step 5 by risk rating per vegetation type such that each group of species with the same conservation significance status in each risk rating per vegetation type was assigned a score.

6. Scores for each group of species with the same conservation significance status in each risk rating were summed per vegetation type to obtain a final score for each vegetation type.

7. Scores for each vegetation type were examined for groupings in score values. Broad categories were then assigned where scores were closely clumped. The categories were those depicting the value of vegetation types to threatened fauna species. Categories were:

- High (final scores above 115);
- Moderate (final scores between 81 and 115); and
- Low (final scores below 80).

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Appendix G: Ecological scouting framework

This appendix presents an ecological scouting framework designed to minimise impacts on a range of biodiversity values as part of the field scouting process.

Key biodiversity values within the study area include:

- Riparian corridors
- Threatened species and endangered ecological communities
- Hollow-bearing trees
- Significant fauna habitat features

The ecological scouting framework considers the significance of each value against legislative requirements, other policy/approval requirements and potential offsetting requirements. Key legislation and policy/approval requirements include:

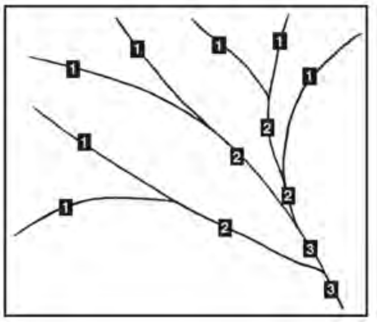
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- NSW *Environmental Planning and Assessment Act 1979* (EPA Act)
- NSW *Threatened Species Conservation Act 1995* (TSC Act)
- NSW *Fisheries Management Act 1994* (FM Act)
- NSW *Water Management Act 2000* (WM Act)
- State Environmental Planning Policy 44 (Koala Habitat)
- *Guidelines for riparian corridors on waterfront land* (DPI, 2012)

Due to the disperse nature of natural gas infrastructure, not all impacts can be avoided across the full range of biodiversity values present. For each of the key biodiversity values, a thorough consideration has been made against the policy framework to prioritise impact minimisation process both within and between values (**Table 1**).

Ecological Field Scouting Procedure

1. Desktop assessment (preliminary constraints analysis)
    a. Buffer well pads by 50 m (4 ha area) and linear infrastructure by 5 m (20 m corridor)
    b. Review mapped watercourses and riparian corridors
    c. Review aerial photography
    d. Review Ecological Sensitivity Analysis
    e. Review vegetation mapping
    f. Review Pilliga Mouse habitat model
    g. Review canopy height model (CHM)
    h. Based on (a) to (g) identify and map preliminary constraints
2. Undertake field survey within buffered area (1a) collecting GPS data for biodiversity values (**Table 1**) which allows infrastructure micro-siting to be undertaken post-fieldwork.
3. Undertake a post-field micro-siting exercise utilising the Ecological Scouting Framework (**Table 2**) and a set of design principles (e.g. maximum angles of bends in access tracks, orientation of well sites etc.).

Table 1: Review of and categorisation of biodiversity values

<table>
<tr><th>Ecological value</th><th colspan="2">Detail</th></tr>
<tr><td>Riparian corridors
</td><td colspan="2">As part of the Narrabri Gas project, watercourses have been mapped at a 1:15,000 scale (including banks mapped (5th and 6th order) or modelled (1st to 4th order)), categorised by stream order, and the appropriate riparian corridor widths applied.</td></tr>
<tr><td rowspan="8">Threatened flora species and ecological communities</td><td colspan="2">Threatened flora species and ecological communities are to be ranked based on their relative legislative status with those values having higher legislative status being afforded more protection.
Due their mobile nature, threatened fauna species are considered in the hollow-bearing tree and specific fauna habitat section.</td></tr>
<tr><td>Ranking (highest to lowest)</td><td>Status</td></tr>
<tr><td>1</td><td>EPBC Act Critically Endangered</td></tr>
<tr><td>2</td><td>TSC Act Critically Endangered</td></tr>
<tr><td>3</td><td>EPBC Act Endangered</td></tr>
<tr><td>4</td><td>TSC Act Endangered</td></tr>
<tr><td>5</td><td>EPBC Act Vulnerable</td></tr>
<tr><td>6</td><td>TSC Act Vulnerable</td></tr>
<tr><td>Hollow-bearing trees and logs</td><td colspan="2">Hollow-bearing trees and logs provide habitat for a range of hollow-dependant fauna including mammals, birds and reptiles. Ecological studies have shown that hollows are likely to be a limiting factor in the distribution and populations of native fauna species.
Previous studies have located hollow-bearing trees used as nest sites for Barking Owl in the study area. Nest sites are reused by breeding pairs and are important habitat features for Barking Owl. It is important to maintain suitable habitat surrounding the nest tree such that it can remain viable.
Due to past logging activities and frequent high-intensity bushfire there is a relative paucity of large hollows (>300 mm) in the study area.</td></tr>
</table>

<table>
<tr><th>Ecological value</th><th colspan="2">Detail</th></tr>
<tr><td rowspan="5"></td><td colspan="2">Hollow-bearing trees are to be classified based on their relative size class</td></tr>
<tr><td>Ranking (highest to lowest</td><td>Size Class</td></tr>
<tr><td>1</td><td>> 300 mm</td></tr>
<tr><td>2</td><td>≥200 mm < 300 mm</td></tr>
<tr><td>3</td><td><200 mm</td></tr>
<tr><td rowspan="5">Significant fauna habitat features</td><td colspan="2">The study area contains a range of fauna habitat values such as Pilliga Mouse habitat, stick nests and food sources (e.g. mistletoe).</td></tr>
<tr><td>Value</td><td>Recommendation</td></tr>
<tr><td>Pilliga Mouse Habitat</td><td>Maximise avoidance</td></tr>
<tr><td>Nests (e.g. old stick nests that are reused by threatened birds of prey).</td><td>Maximise avoidance</td></tr>
<tr><td>Mistletoe (in particular Amyema spp.)</td><td>Avoid where possible</td></tr>
</table>

Table 2: Ecological Scouting Framework

Ranking (priority highest to lowest)	Description	Action
1	Riparian Corridors	**Avoid impacts** of well pads on designated riparian corridors and mapped wetland habitat (dams) **Avoid impacts** of linear infrastructure on mapped wetland habitat (dams) Maximise avoidance of designated riparian corridors No additional crossings of Bohena Creek (linear infrastructure to follow existing crossings only).
2	Known Barking Owl nest trees	**Avoid impacts** of well pads and linear infrastructure on known Barking Owl nest trees and vegetation within a 50 m buffer of the known nest tree. OEH holds a register of known Barking Owl nest trees. This register should be sought before commencing infrastructure design.
3	Endangered ecological communities	**Maximise avoidance** of well pads and linear infrastructure on endangered ecological communities

Ranking (priority highest to lowest)	Description	Action
4	Threatened flora species	**Maximise avoidance** for well pads and linear infrastructure. Impacts to threatened flora species and ecological communities should be assessed according to the ranking outlined in **Table 1** with those values having higher legislative status being afforded more protection. Consideration of the number of individuals of each flora species to be impacted in each status category may be required on a case by case basis (e.g. should 1 endangered individual be retained over 10 vulnerable species). Consideration should be given to the total modelled population (and relatively rarity) of each species within the study area to make an informed decision regarding avoidance.
5	Hollow bearing trees and logs	**Maximise avoidance** for well pads and linear infrastructure. Impacts to hollow-bearing trees should be assessed according to the ranking outlined in **Table 1** with those values having higher ecological significance being afforded more protection.
6	Pilliga Mouse habitat	**Maximise avoidance** of well pads and linear infrastructure on Pilliga Mouse habitat
7	Nest trees	**Maximise avoidance** for well pads and linear infrastructure.
8	Trees with mistletoe (particularly *Amyema* spp.)	Trees with mistletoe should be avoided where possible as they support Painted Honeyeater and other threatened fauna foraging habitat. Seek to minimise impacts on trees supporting mistletoe for well pads and linear infrastructure .

Appendix H: Clearing procedure

The following clearing procedure has been developed to minimise potential impacts or risk to fauna during construction. The purpose of the procedure is to encourage fauna to relocate outside of the disturbance footprint prior to habitat clearing or alternatively move fauna during clearing. A pre-clearing survey by appropriately trained ecologists is required to be undertaken prior to commencing clearing. The pre-clearing survey includes marking all hollow-bearing trees or other significant fauna habitat features (nests, hollow bearing logs and stags) with yellow and black striped flagging tape and recording the location using a GPS.

The clearing procedure outlines best practise and is designed to be adaptive depending on site-specific conditions that arise during clearing. The clearing procedure will follow four steps:

1. Planning
2. Slash shrub and ground layer
3. Tap hollow-bearing trees
4. Remove hollow-bearing trees

Prior to the commencement of clearing, the boundary of the active works area should be clearly marked in the field to ensure all clearing and construction activities occur within the approved footprint. All access to active work areas should be through existing roads and designated service corridors.

Step 1: Planning

1. All appropriate licences with respect to working with native fauna are to be obtained prior to clearing.
    a. Ecologists working with fauna require a current scientific licence issued by the NSW Office of Environment and Heritage and ethics approval issued by the Animal Welfare Unit of the NSW Department of Primary Industries.
    b. Project Approval is required.
2. The nearest veterinary clinic should be notified of the clearing works prior to clearing commencing and their phone number on hand if fauna are injured or distressed.
    a. Veterinary clinic:
        a. Practice: Western Namoi Veterinary Clinic
        b. Principal Vet: Dr Michael Reed
        c. Contact: 02 6792 2577
        d. Address: 24 Francis Street, Narrabri.
    a. WIRES: 13 000 WIRES or 13 000 94737
    b. WIRES (central northern branch): 1300 131 554
3. Discuss clearing procedure, equipment / machinery required, schedule. All staff and contractors involved in the clearing will undertake the ecological induction prior to commencing work.

Step 2: Slash shrub and ground layer

Clearing of shrub and groundcover vegetation (under-scrubbing) around the hollow-bearing trees can commence once habitat features have been surveyed and marked to encourage dispersal of fauna from the active features. Under-scrubbing should be undertaken at least one day prior to removal of hollow-bearing trees to allow fauna time to self-relocate from the disturbance footprint.

Step 3: Tap hollow-bearing trees

1. Hollow-bearing trees are to be agitated (nudged by heavy machinery or with a chainsaw) the day prior to felling and left over night.
2. Active roosts, dens or dormitories are to be re-inspected following agitation to confirm absence of fauna prior to clearing.

Step 4: Removing HBTs

1. A suitably qualified fauna ecologist with training/experience in fauna capture and rescue is to be present during the felling process.
2. Pre-felling procedures for all trees to be felled will include a visual inspection for fauna immediately prior to tree removal and care should be taken to allow all fauna to vacate a given tree prior to felling. Each tree is to be nudged and shaken immediately prior to felling to encourage fauna such as birds to vacate the tree. Felling cannot commence until the supervising ecologist has signalled that it is safe to do so.
3. The “slow drop” technique is to be attempted when removing all hollow-bearing trees. This technique aims to lower hollow-bearing trees to the ground whilst minimising disturbance to hollows. This involves nudging and shaking the tree, followed by lowering of the tree to the ground. Practical execution of this method may involve the use of the bull dozer blade or mulcher bar to push the tree mid-trunk to initiate felling, followed by lowering the blade / bar to the base of the tree trunk. It is essential to ensure that suitable exclusion zones are implemented during these activities and personnel are not exposed to increased risk by implementing these procedures. Job Hazard Analyses (JHAs) and stepback are to be completed prior to completing felling activities.
4. Once on the ground, hollows are to be inspected for resident fauna (fibre optic camera technology is useful for deeper and angled hollows). If injured or juvenile fauna are present they must be cared for. Injured fauna should be taken to the veterinary clinic (details above). Juvenile fauna should be taken to WIRES if it is not possible to relocate them to a suitable location. The ability for the parents to continue to care for the juvenile fauna should be considered at this stage. Fauna captured and not requiring treatment are to be relocated into the same habitat near the point of rescue at dusk or left inside the hollow. Trees are to be left on the ground overnight giving fauna trapped in the trees an opportunity to escape. Hollows with fauna left inside should be re-checked the following day to ensure the fauna have self-relocated during the evening.
5. All data on species and number of hollow dependent fauna are to be recorded.
6. Some of the hollow-bearing trees or other significant fauna habitat features should be relocated to adjoining vegetation or moved into areas of rehabilitation where feasible.
7. Note that if fauna are observed to be in the tree that cannot self-relocate (e.g. chicks that haven’t yet fledged) it may be necessary to contact an appropriately trained ecologist and/or wildlife carer to be present to encourage the removal and provide care for the animal/s. While translocation of fauna is not ideal, the *OEH Policy for the translocation of threatened fauna in NSW* are to be followed in these circumstances.

Communication

Positive communication between the ecologist supervising the clearing and the machinery operator is paramount to clearing being undertaken in a safe and efficient manner. Communication will operate by the following procedure:

1. Daily discussion prior to work commencing, outlining the areas of operation for the day.
2. A 2-way radio will be used for communication which will be set on a dedicated channel.
3. The ecologist will outline the clearing procedure to be followed. This will include outlining the following communication points during the clearing process:
    a. Confirm location ecologist should stand to observe felling. The minimum safe distance when felling will be determined by the height of the tree plus an extra 10 m for observer safety (expected to be 30 m). If the mulcher drum is operational, the safe distance will be a minimum of 100 m.
    b. ‘Ok to tap’ to nudge the tree.
    c. ‘Ok to start’ to start felling the tree.
    d. ‘Ok to access’ for ecologist to inspect hollows in felled tree (once felling has been completed and machinery has been switched off).
    e. ‘Stop work’ to stop clearing due to fauna observed or a safety concern.

Lessons learnt

Previous experience in tree-felling operations have informed us of potential risks involved in the clearing operations. Areas of high risk are:

- Lack of positive communication increases the risk associated with the ecologist entering the exclusion zones and the risk of potentially injuring fauna during the clearing process.
- Not allowing adequate time between slashing vegetation, hollow-bearing tree tapping and hollow-bearing tree removal can increase the occurrence of fauna during felling.
- Not allowing adequate time for felled hollow-bearing trees to remain undisturbed can lead to increased risk to fauna.

Appendix I: Likelihood table

Provided below are the likelihood tables for threatened species listed under the NSW TSC Act and Commonwealth EPBC Act. Species, populations and communities considered to have the potential to occur are highlighted in yellow, those likely to occur are highlighted in brown, and those which are known occur are highlighted in green. The distribution and habitat information has been obtained from the Threatened species profiles (OEH, 2016b) unless otherwise indicated.

Key to the table:

- TSC Status = Listing under the *Threatened Species Conservation Act 1995*
- EPBC Status = Listing under the *Environment Protection and Biodiversity Conservation Act 1999*
- CE = Critically Endangered
- E = Endangered (EPBC Act)
- E1 = Endangered (TSC Act)
- E2 = Endangered Population (TSC Act)
- E4 = Extinct (TSC Act)
- V = Vulnerable
- M = Migratory (EPBC Act)
- Mar = Marine (EPBC Act)

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
FAUNA							
Aepyprymnus rufescens	Rufous Bettong	V	~	The original range from Coen in north Queensland to central Victoria has been reduced to a patchy distribution from Cooktown, Queensland, to north-eastern NSW as far south as Mt Royal National Park. In NSW it has largely vanished from inland areas but there are sporadic, unconfirmed records from the Pilliga and Torrington districts.	Prefers forests with a grassy to sparse understorey, from tall wet sclerophyll forests on the coast to the dry forests and open woodlands west of the Great Dividing Range. In the day they shelter in a grassy nest constructed in a shallow depression at the base of a tussock or fallen log (Dennis & Johnson, 2008).	Moderate	Potential
Alectura lathami	Australian Brush-turkey	E2	~	Largely coastal distribution from Cape York south as far as the Illawarra in NSW. A population of the Australian Brush-turkey is known from the Nandewar and Brigalow Belt South Bioregions. Recent records for the species show the population to range from north east of Warialda, to Narrabri, approximately 115 km to the south-west, and occur within the local government areas of Yallaroi, Bingara, Narrabri, Barraba and Moree Plains.	Occurs in forested and wooded areas of tropical and warm-temperate districts, particularly above 300 m to at least 1200 m altitude. In NSW the inland vegetation type preferred is a dry rainforest community that is found within the Semi-evergreen Vine Thicket in the Brigalow Belt South and Nandewar Bioregions Endangered Ecological Community.	Low	Unlikely
Anomalopus mackayi	Five-clawed Worm-skink	E1	V	Patchy distribution on the North West Slopes and Plains of north-east NSW and south-east Queensland, from the Ashford area west to Mungindi and Walgett in NSW and north to Dalby in Queensland. No recent or historical records occur within the study area and its likely distribution within the Namoi River catchment extends to just north of the study area (North West Ecological Services, 2010). Recent record from Gun Club Road is likely to be a residential address (OEH, 2016a).	Close to or on the lower slopes of slight rises in grassy White Box woodland on moist black soils, and River Red Gum-Coolibah-Bimble Box woodland on deep cracking loose clay soils. May also occur in grassland areas and open paddocks with scattered trees. Live in permanent deep tunnel-like burrows and deep soil cracks, coming close to the surface under fallen timber and litter, especially partially buried logs.	Low	Unlikely
Anseranas semipalmata	Magpie Goose	V	Mar	Still relatively common in the northern Australian tropics, from Fitzroy River in Western Australia across to Rockhampton in Queensland, but disappeared from south-east Australia by 1920 due to drainage and overgrazing of reed swamps used for breeding. Since the 1980s, however, there have been an increasing number of records in central and northern NSW, and vagrants can even follow food sources to south-eastern NSW. This species is known north of the study area, mainly around Narrabri Lake and Wee Waa (OEH, 2016a). It has not been recorded in the study area.	Mainly found in shallow (less than 1 metre deep) sedge or rush-dominated wetlands; mainly those on floodplains of rivers (Marchant & Higgins, 1993; Simpson & Day, 2010). The species forages in terrestrial as well as aquatic habitats, including grasslands, pastures, wetlands, well-vegetated dams and crops. It roosts in tall vegetation and nests are formed in trees over deep water or on a floating platform of flattened reeds.	Moderate	Potential
Anthochaera phrygia	Regent Honeyeater	CE	CE, M	An extremely patchy distribution across the inland slopes of south-east Australia between north-eastern Victoria and south-eastern Queensland. Birds are also found in drier coastal woodlands and forests in some years. In NSW, most records are from the Great Dividing Range, mainly on the North-West Plains, North-West and South-West Slopes, Northern Tablelands, Central Tablelands and Southern Tablelands regions; as well as the Central Coast and Hunter Valley regions. Regent Honeyeaters have been recorded sporadically in the Pilliga (in 1991, 1992, 1997 and 2003; OEH 2014a).	Associated with temperate eucalypt woodland and open forest including forest edges, wooded farmland and urban areas with mature eucalypts, and riparian forests of Casuarina cunninghamiana (River Oak) (Garnett, 1993). The Regent Honeyeater primarily feeds on nectar from box and ironbark eucalypts and occasionally from banksias and mistletoes. Eucalypts that reliably produce large amounts of nectar occurring in the Pilliga are *E. sideroxylon, E. melliodora* and *E. albens*.	High	Potential
Aprasia parapulchella	Pink-tailed Legless Lizard	V	V	Known only to occur in the Central and Southern Tablelands and South Western Slopes of NSW. Populations have been recorded in the Queanbeyan/Canberra district, Cooma, Yass, Bathurst, Albury and West Wyalong areas.	Inhabits open woodland that has a predominately native grass understorey that is situated on sloping, well-drained soils with rocky outcrops or scattered partially buried rocks present. Burrows are formed beneath small, partially embedded	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
					rocks that are often inhabited by small black ants and termites.		
Apus pacificus	Fork-tailed Swift	-	M Mar	A non-breeding visitor to all states and territories of Australia. In NSW, the Fork-tailed Swift is recorded in all regions. Many records occur east of the Great Divide, however, a few populations have been found west of the Great Divide. These are widespread but scattered further west of the line joining Bourke and Dareton. Sightings have been recorded at Milparinka, the Bulloo River and Thurloo Downs (DotE, 2014c).	Varied habitat with a possible tendency to more arid areas but also over coasts and urban areas (Simpson & Day, 2010).	High	Known
Ardea ibis	Cattle Egret	~	M, Mar	Widespread and common species in Australia. recorded in the northern portion of the study area (DotE, 2014a).	Occur in tropical and temperate grasslands, wooded lands and terrestrial wetlands, and very rarely in arid and semi-arid regions. It uses predominately shallow, open and fresh wetlands including meadows and swamps with low emergent vegetation and abundant aquatic flora.	Moderate	Known
Ardea modesta	Great Egret, White Egret	~	M, Mar	Widespread in Australia. They occur in all states/territories of mainland Australia and in Tasmania. They have also been recorded as vagrants on Lord Howe, Norfolk and Macquarie Islands (DotE, 2014a).	Reported in a wide range of wetland habitats including swamps and marshes; margins of rivers and lakes; damp or flooded grasslands, pastures or agricultural lands; reservoirs; sewage treatment ponds; drainage channels; salt pans and salt lakes; salt marshes; estuarine mudflats, tidal streams; and mangrove swamps (Kushlan & Hancock, 2005; Marchant & Higgins, 1990).	Moderate	Known
Ardeotis australis	Australian Bustard	E1	~	Occurs in inland Australia and is now scarce or absent from southern and south-eastern Australia. In NSW, they are mainly found in the north-west corner and less often recorded in the lower western and central west plains regions. Occasional vagrants are still seen as far east as the western slopes and Riverine plain. Breeding now only occurs in the north-west region of NSW.	Mainly inhabits tussock and hummock grasslands, though prefers tussock grasses to hummock grasses; also occurs in low shrublands and low open grassy woodlands; occasionally seen in pastoral and cropping country, golf courses and near dams.	High	Potential
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	~	The eastern population is found from Atherton Tableland, Queensland south to Tasmania and west to Eyre Peninsula, South Australia.	Found in open forests and woodlands, and may be seen along roadsides and on golf courses.	High	Known
Botaurus poiciloptilus	Australasian Bittern	E1	E	Widespread but uncommon over south-eastern Australia. In NSW they may be found over most of the state except for the far north-west.	Tussock and hummock grasslands, preferring the former to the latter. It also occurs in low shrublands and low open grassy woodlands, and is occasionally seen in pastoral and cropping country, golf courses and near dams.	Low	Potential
Burhinus grallarius	Bush Stone-curlew	E1	~	Found throughout Australia except for the central southern coast and inland, the far south-east corner, and Tasmania. Only in northern Australia is it still common however and in the south-east it is either rare or extinct throughout its former range.	Occurs in lowland grassy woodland and open forest (DEC, 2006). West of the Great Dividing Range, Bush Stone-curlews are associated with Grey Box (*Eucalyptus microcarpa*), River Red Gum (*E. camaldulensis*), Black Box (*E. largiflorens*) and Yellow Box (*E. melliodora*), with a sparse ground cover of native grasses and few or no shrubs (Johnson & Baker-Gabb, 1994; Marchant & Higgins, 1993). They also occasionally occur in box-ironbark forests and patches of she-oaks (*Allocasuarina* spp.).	High	Potential
Calidris acuminata	Sharp-tailed Sandpiper		M, Mar	Spends the non-breeding season in Australia with small numbers occurring regularly in New Zealand. Most of the population migrates to Australia, mostly to the south-east and are widespread in both inland and coastal locations and in both freshwater and saline	Prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and	Low	Potential

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
				habitats. Many inland records are of birds on passage (Marchant & Higgins, 1993).	hypersaline saltlakes inland. They also occur in saltworks and sewage farms. They use flooded paddocks, sedgelands and other ephemeral wetlands, but leave when they dry (Higgins & Davies, 1996).		
Calyptorhynchus banksii (inland subspecies)	Red-tailed Black-Cockatoo	V	~	Ranges broadly across much of northern and western Australia as well as western Victoria. In NSW, one population occurs on the north-western slopes and plains but another small isolated population is found in the coastal north-east. .	Occurs in coastal forests and woodlands or inland open shrubland near water (Simpson & Day, 2010). This species is noted to feed mainly on seeds, especially of eucalypts, casuarinas, acacia and banksias. May also take berries, nectar, flowers and occasionally insects and their larvae (Marchant & Higgins, 1993).	Moderate	Unlikely
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	~	Uncommon although widespread throughout suitable forest and woodland habitats, from the central Queensland coast to East Gippsland in Victoria, and inland to the southern tablelands and central western plains of NSW, with a small population in the Riverina. An isolated population exists on Kangaroo Island, South Australia	Associated with a variety of open eucalypt forest and woodland types containing a midstorey of sheoaks (*Allocasuarina* spp. and *Casuarina* spp.). This vegetation is usually indicative of the poor nutrient status of underlying soils (S.T. Garnett & Crowley, 2000). In the study area, this species was observed feeding on *Allocasuarina diminuta* subsp. *diminuta* and *Callitris* spp..	High	Known
Cercartetus nanus	Eastern Pygmy-possum	V	~	Found in south-eastern Australia, from southern Queensland to eastern South Australia and in Tasmania. In NSW it extends from the coast inland as far as the Pilliga, Dubbo, Parkes and Wagga Wagga on the western slopes.. It occupies small home ranges, rarely greater than 1 ha.	Found in wet and dry eucalypt forest, subalpine woodland, coastal banksia woodland and wet heath (Menkhorst & Knight, 2004). In general woodlands and heath are its preferred habitat. Small tree hollows are favoured for nesting during the day, but nests have also been found under bark, in rotten stumps, holes in the ground, old bird nests, Ringtail Possum drays, thickets of vegetation and in the branch forks of tea-trees (Turner & Ward, 1995).	Moderate	Known
Certhionyx variegatus	Pied Honeyeater	V	~	Widespread throughout acacia, mallee and Spinifex scrubs of arid and semi-arid Australia. Occasionally occurs further east, on the slopes and plains and the Hunter Valley, typically during periods of drought.	Inhabits wattle shrub (primarily Mulga, Acacia aneura), mallee, Spinifex and eucalypt woodlands, usually when shrubs are flowering; feeds on nectar, predominantly from various species of emu-bushes (*Eremophila* spp.); also from mistletoes and various other shrubs (e.g. *Brachystema* spp. and *Grevillea* spp.); also eats saltbush fruit, berries, seed, flowers and insects. Highly nomadic, following the erratic flowering of shrubs; can be locally common at times	Low	Unlikely
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Found mainly in areas with extensive cliffs and caves, from Rockhampton in Queensland south to Bungonia in the NSW Southern Highlands. It is generally rare with a very patchy distribution in NSW. There are scattered records from the New England Tablelands and North West Slopes, including the Southern Pilliga forest area.	Recorded in a variety of habitats, including wet and dry sclerophyll forests, Cyprus Pine dominated forest, woodland, sub-alpine woodland, edges of rainforests and sandstone outcrop country (DotE, 2014c). This species roosts in caves, rock overhangs and disused mine shafts and as such is usually associated with rock outcrops and cliff faces (Churchill, 2008). It also possibly roosts in the hollows of trees (Duncan, Baker, & Montgomery, 1999).	High	Potential
Chalinolobus picatus	Little Pied Bat	V	~	Found in inland Queensland and NSW (including Western Plains and slopes) extending slightly into South Australia and Victoria. The species has been detected within the study area, predominately in the north-western section of the study area, although the species was also recorded in the south, in Pilliga East State Forest and Bibblewindi State Forest.	Found in a wide range of habitats, including dry open forest, open woodland, mulga woodlands, chenopod shrublands, cypress-pine forest, mallee and Bimbil box woodland. It mainly roosts in tree hollows (G. I. Ford, Pennay, Young, & Richards, 2008), but also uses caves, rock outcrops, mine shafts, tunnel and buildings.	High	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
Chthonicola sagittata	Speckled Warbler	V	~	Patchy distribution throughout south-eastern Queensland, the eastern half of NSW and into Victoria, as far west as the Grampians. The species is most frequently reported from the hills and tablelands of the Great Dividing Range, and rarely from the coast. There has been a decline in population density throughout its range, with the decline exceeding 40% where no vegetation remnants larger than 100ha survive. The Speckled Warbler has been recorded throughout the study area and previous records are throughout the Pilliga (OEH, 2016a).	Occupies a wide range of eucalypt-dominated communities with a grassy understorey, often on rocky ridges or in gullies. Typical habitat includes scattered native tussock grasses, a sparse shrub layer, some eucalypt regrowth and an open canopy.	High	Known
Circus assimilis	Spotted Harrier	V	~	The Spotted Harrier occurs throughout the Australian mainland, except in densely forested or wooded habitats of the coast, escarpment and ranges, and rarely in Tasmania. Individuals disperse widely in NSW and comprise a single population .	Occurs in grassy open woodland including acacia and mallee remnants, inland riparian woodland, grassland and shrub steppe. It is found most commonly in native grassland, but also occurs in agricultural land, foraging over open habitats including edges of inland wetlands.	Moderate	Known
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	~	The western boundary of the range runs approximately through Corowa, Wagga Wagga, Temora, Forbes, Dubbo and Inverell and along this line the subspecies intergrades with the arid zone subspecies of Brown Treecreeper *Climacteris picumnus picumnus* which then occupies the remaining parts of the state.	Found in eucalypt woodlands (including Box-Gum Woodland) and dry open forest of the inland slopes and plains inland of the Great Dividing Range. It mainly inhabits woodlands dominated by stringybarks or other rough-barked eucalypts, usually with an open grassy understorey, sometimes with one or more shrub species.	High	Unlikely The study area lies outside of the geographically defined area for the eastern subspecies
Crinia sloanei	Sloane's Froglet	V	~	Recorded from widely scattered sites in the floodplains of the Murray-Darling Basin, with the majority of records in the Darling Riverine Plains, NSW South Western Slopes and Riverina bioregions in New South Wales. It has not been recorded recently in the northern part of its range and has only been recorded infrequently in the southern part of its range in NSW . Known habitat is to the west of the study area.	It is typically associated with periodically inundated areas in grassland, woodland and disturbed habitats.	Moderate	Unlikely
Daphoenositta chrysoptera	Varied Sittella	V	~	Widespread in mainland Australia. Distribution in NSW is nearly continuous from the coast to the far west .	Found in eucalypt woodlands and forests throughout their range. They prefer rough-barked trees like stringybarks and ironbarks or mature trees with hollows or dead branches .	High	Known
Dasyurus maculatus	Spotted-tailed Quoll	V	E	Now found on the east coast of NSW, Tasmania, eastern Victoria and north-eastern Queensland.	Inhabits a range of environments including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Den sites are found in hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky-cliff faces.	Moderate	Potential
Delma torquata	Collared Delma	~	V	The main concentrations of records are from the western suburbs of Brisbane. Not recorded previously in NSW (DotE, 2014c).	Normally inhabits eucalypt or acacia dominated woodland and open forest where it is associated with suitable microhabitats (exposed rocky outcrops, or a sparse understorey of tussock grass, shrubs or semi-evergreen vine thickets). Leaf Litter appears to be an essential part of the microhabitat and is always present (DotE, 2014c).	Low	Unlikely Current and predicted distribution doesn't overlap with study area.
Drymodes brunneopygia	Southern Scrub-robin	V	~	Restricted southern Australia and in NSW is confined to two main areas. The first is in central NSW and is centred on Round Hill and Nombinnie Nature	Inhabits mallee and acacia scrub, particularly with dense sub-shrubs in the understorey, including Broombush and other dry shrubs	Moderate	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
				Reserves, though suitable habitat probably exists on adjoining leasehold lands. The other population occurs in the far south west of NSW, mainly within the Scotia mallee centred on Tarawi NR and Scotia Sanctuary			Current and predicted distribution doesn't overlap with study area.
Ephippiorhynchus asiaticus	Black-necked Stork	E1	~	Widespread in coastal and subcoastal northern and eastern Australia, south to central-eastern NSW and with vagrants recorded at scattered sites well away from the coast (for example, near Moree, north-east of Hay and in Victoria). In NSW, the species becomes more uncommon south of the Northern Rivers region, and rarely occurs south of Sydney . Recorded at Yarrie Lake by Central Coast Bird Observers in 2012 (OEH, 2016a).	Associated with tropical and warm temperate terrestrial wetlands, estuarine and littoral habitats, and occasionally woodlands and grasslands floodplains (Marchant & Higgins, 1993). Forages in fresh or saline waters up to 0.5m deep, mainly in open fresh waters, extensive sheets of shallow water over grasslands or sedgeland, mangroves, mudflats, shallow swamps with short emergent vegetation and permanent billabongs and pools on floodplains (Marchant & Higgins, 1993).	Low	Known
Epthianura albifrons	White-fronted Chat	V	~	Found across the southern half of Australia. It is found mostly in temperate to arid climates and very rarely sub-tropical areas, and it occupies foothills and lowlands up to 1000 m above sea level. In NSW, it occurs mostly in the southern half of the state, in damp open habitats along the coast, and near waterways in the west.	Gregarious species, usually found foraging on bare or grassy ground in wetland areas.	Low	Unlikely
Erythrotriorchis radiatus	Red Goshawk	CE	V	Found from across northern Australia, down the east coast of Qld and into the northern coast of NSW. In NSW records are rare. Listed as having occurred south to Port Stephens. Records within NSW in the last 30 years are limited to the NSW Northern Rivers and Northern Tablelands regions.	Its habitat consists of wooded and forested areas. Prefers forest and woodland with a mosaic of vegetation types, large populations of birds for prey and permanent water. Riverine vegetation is highly utilised by this species.	Moderate	Unlikely Current and predicted distribution doesn't overlap with study area.
Falco hypoleucos	Grey Falcon	E1	~	Found throughout the arid and semi-arid zones of Australia. It is sparsely distributed in NSW, found chiefly throughout the Murray-Darling Basin, with the occasional vagrant east of the Great Dividing Range.	Usually restricted to shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it is occasionally found in open woodlands near the coast. Also occurs near wetlands where surface water attracts prey .	Moderate	Potential
Falco subniger	Black Falcon	V	~	Widely but sparsely distributed in NSW, occurring mostly in inland regions. In New South Wales there is assumed to be a single population that is continuous with a broader continental population, given that falcons are highly mobile, commonly travelling hundreds of kilometres (Marchant & Higgins, 1993).	Inhabits woodland, shrubland and grassland in the arid and semi-arid zones, especially wooded watercourses and agricultural land with scattered remnant trees. The Black Falcon is usually associated with streams or wetlands, visiting them in search of prey and often using standing dead trees as lookout posts.	Moderate	Known
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	~	Found on the south-east coast and ranges of Australia, from southern Queensland to Victoria and Tasmania. In NSW records extend to the western slopes of the Great Dividing range. The study area is considered outside their normal range.	Prefers tall (greater than 20m) moist habitats predominately roosting in Eucalypt tree hollows. They have also been found to roost under loose bark on trees and in man-made structures.	Low	Unlikely
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	~	M, Mar	Recorded along the east coast of Australia from Cape York Peninsula through to south-eastern South Australia. The range extends inland over the eastern tablelands in south-eastern Queensland (and occasionally from Rockhampton in the north), and to west of the Great Dividing Range in New South Wales (DotE, 2014c).	Occurs in permanent and ephemeral wetlands up to 2000 m above sea-level, usually inhabiting open, freshwater wetlands with low, dense vegetation such as swamps, flooded grasslands or heathlands, around bogs and other water bodies. This species can also occur in habitats with saline or brackish water and in modified or artificial habitats.	Low	Potential

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
Geophaps scripta scripta	Squatter Pigeon	E	V	Occurs on the inland slopes of the Great Dividing Range. Its distribution extends from the Burdekin-Lynd divide in central Queensland, west to Charleville and Longreach, east to the coastline between Proserpine and Port Curtis (near Gladstone), and south to scattered sites though out south-eastern Queensland. Its distribution historically extended into NSW however; there have been no confirmed records of the species in NSW since the 1970s.	Occurs mainly in grassy woodlands and open forests that are dominated by eucalypts. It has also been recorded in sown grasslands with scattered remnant trees, disturbed habitats. The species is commonly observed in habitats that are located close to bodies of water.	Low	Unlikely
Glossopsitta pusilla	Little Lorikeet	V	~	Distributed widely across the coastal and Great Divide regions of eastern Australia from Cape York to South Australia. NSW provides a large portion of the species' core habitat, with lorikeets found westward as far as Dubbo and Albury. Nomadic movements are common, influenced by season and food availability, although some areas retain residents for much of the year and 'locally nomadic' movements are suspected of breeding pairs .	Mostly occur in dry, open eucalypt forests and woodlands. They have been recorded from both old-growth and logged forests in the eastern part of their range, and in remnant woodland patches and roadside vegetation on the western slopes. They feed primarily on nectar and pollen in the tree canopy, particularly on profusely-flowering eucalypts, but also on a variety of other species including melaleucas and mistletoes. On the western slopes and tablelands Eucalyptus albens and E. melliodora are important food sources for pollen and nectar respectively.	High	Known
Grantiella picta	Painted Honeyeater	V	V	Occurs at low densities throughout its range. The greatest concentrations of the bird (and almost all breeding), occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern QLD. During the winter it is more likely to be found in the north of its distribution	Inhabits Boree, Brigalow and Box-Gum Woodlands and Box-Ironbark Forests. It feeds on mistletoes growing on woodland eucalypts and acacias. It nests from spring to autumn in a small, delicate nest hanging within the outer canopy of drooping eucalypts, she-oak, paperbark or mistletoe branches.	High	Known
Grus rubicunda	Brolga	V	~	Formerly found across Australia, except for the south-east corner, Tasmania and the south-western third of the country. It still abundant in the northern tropics, but very sparse across the southern part of its range .	Inhabits large open wetlands (including ephemeral and permanent swamps), grassy plains, coastal mudflats and irrigated croplands and, on the coast, mangrove-studded creeks and estuaries. It is less common in arid and semi-arid regions, but will occur close to water in these areas. Brolgas will feed in dry grassland or ploughed paddocks; however, they also depend on access to wetland habitats.	Low	Potential
Haliaeetus leucogaster	White-bellied Sea-Eagle	~	Mar	Distributed along the coastline of mainland Australia and Tasmania. It also extends inland along some of the larger waterways, especially in eastern Australia. The inland limits of the species are most restricted in south-central and south-western Australia, where it is confined to a narrow band along the coast (DotE, 2014c).	Areas of large open water bodies. It has been recorded at or in the vicinity of freshwater swamps, rivers, lakes, reservoirs, billabongs, saltmarsh and sewage ponds, as well as coastal waters. Terrestrial habitats include coastal dunes, tidal flats, grassland, heathland, woodland, forest and even urban areas.	Moderate	Known (Note that this species was removed from the migratory list in the EPBC Act on 30 June 2015 and hence doesn't need assessment of significance using EPBC Act)
Hamirostra melanosternon	Black-breasted Buzzard	V	~	Found sparsely in areas of less than 500 mm rainfall, from north-western NSW and north-eastern South Australia to the east coast at about Rockhampton, then across northern Australia south almost to Perth, avoiding only the Western Australian deserts .	Lives in a range of inland habitats including open forests, riverine woodlands, scrubs and heathlands. It is often found along timbered watercourses, which is preferred breeding habitat. It can also hunt over grasslands.	Low	Potential
Hieraaetus morphnoides	Little Eagle	V	~	Found throughout the Australian mainland excepting the most densely forested parts of the Dividing Range escarpment. It occurs as a single population throughout NSW .	Known over woodland and forested lands and open country, extending into the arid zone. It tends to avoid rainforest and heavy forest .It occupies open eucalypt forest, Sheoak and Acacia woodland and riparian woodland within	High	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
					inland NSW. It favours tall living trees for nesting in remnant habitat.		
Hirundapus caudacutus	White-throated Needletail	-	M, Mar	Found throughout eastern and south-eastern Australia. In eastern NSW, it is found to extend inland to the western slopes of the Great Divide and occasionally to the adjacent inland plains (DotE, 2014c).	In Australia, this species is almost exclusively aerial and found over most types of habitat (DotE, 2014c). No breeding habitat in southern hemisphere.	High	Known
Hoplocephalus bitorquatus	Pale-headed Snake	V	~	A patchy distribution from north-east Queensland to north-east NSW. In NSW it occurs from the coast to the western side of the Great Divide as far south as Tuggerah . Historically been recorded in NSW as west as Mungindi and Quambone on the Darling Riverine Plains, across North West Slopes; also form the New England Tablelands.	Wide range of habitats from rain or wet sclerophyll forest to drier eucalypt forests and favours streamside habitat in drier areas. In the study area the species has been found in redgum communities at Yarrie Lake, remnant roadside and regrowth Brigalow vegetation communities.	High	Known
Jalmenus eubulus	Pale Imperial Hairstreak	CE	~	Found in Queensland and NSW. In NSW it is found only in Brigalow -dominated open forests and woodlands in northern areas of the state. Known habitat occurs within remnant Brigalow vegetation communities found to the north of Narrabri..	Suitable habitat is dominated by *Acacia harpophylla* (Brigalow) and *Casuarina cristata* (Belah) on clay soils on flat to gently undulating plants, usually with scattered emergent eucalypts. It is only known to breed in old-growth forest or woodland and does not appear to colonise regrowth habitats after clearing.	Low	Unlikely
Lagorchestes leporides	Eastern Hare-wallaby	E4	Ex	This species once inhabited the interior of New South Wales, Victoria and the Murray River region of South Australia. It was common in the level country between the Murray and Darling rivers, as well as the Liverpool Plains.	Generally spent the day sheltering and foraged at night, it sheltered under large tussocks which it excavated itself. Preferred habitat that consisted of open plains and grasslands.	Low	No
Lathamus discolor	Swift Parrot	E1	CE, Mar	Breeds in Tasmania during spring and summer, migrating in the autumn and winter months to south-eastern Australia from Victoria and the eastern parts of South Australia to south-east Queensland. In NSW mostly occurs on the coast and south west slopes .	On the mainland they occur in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter flowering species such as *Eucalyptus robusta*, *Corymbia maculata*, *C. gummifera*, *E. sideroxylon* and *E. albens* Commonly used lerp infested trees include *E. microcarpa, E. moluccana and E. pilularis* .	High	Potential
Leipoa ocellata	Malleefowl	E1	V, M	The stronghold for this species in NSW is the mallee in the south west centred on Mallee Cliffs NP and extending east to near Balranald and as far north as Mungo NP. In central NSW it has been significantly reduced through land clearance and fox predation and now occurs chiefly in Yathong, Nombinnie and Round Hill NRs and surrounding areas, though birds continue to survive in Loughnan NR .	Dry inland scrub, mallee. Males tend large sand nest-mound (Simpson & Day, 2010).	Low	Unlikely
Leporillus apicalis	Lesser Stick-nest Rat	E4	Ex	In the nineteenth century it occupied a broad area stretching from the Riverina in New South Wales, through most of inland South Australia and into the Gibson Desert, reaching the Western Australian coast in the Gascoyne region (DotE, 2014c).	The Lesser Stick-nest Rat occupied arid and semi-arid lands (DotE, 2014c).	Low	No
Limosa limosa	Black-tailed Godwit	V	~	In NSW, it is most frequently recorded at Kooragang Island (Hunter River estuary). Records in western NSW indicate that a regular inland passage is used by the species, as it may occur around any of the large lakes in the western areas during summer, when the muddy shores are exposed. It has been	Primarily a coastal species, it is usually found in sheltered bays, estuaries and lagoons with large intertidal mudflats and/or sandflats. Further inland, it can also be found on mudflats and in water less than 10 cm deep, around muddy lakes and swamps.	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
				recorded within the Murray-Darling Basin, on the western slopes of the Northern Tablelands and in far north-western NSW.			
Litoria booroolongensis	Booroolong Frog	E1	E	Rrestricted to the tablelands and slopes from 200 m to 1300 m above sea level in NSW and north eastern Victoria. The species is mostly found along the western-flowing streams and their headwaters of the Great Dividing Range. Catchments drain from the Northern Tablelands to the Tumut River in the Southern Highlands, and other tributaries of the Murrumbidgee River. The only records of the species in northern NSW outside the Northern Tablelands are from two streams near Tamworth, NSW.	Typically inhabits rocky western-flowing creeks and their headwaters, although a small number of animals have also been recorded in eastern-flowing streams. along permanent streams with some fringing vegetation cover such as ferns, sedges or grasses (DotE, 2014c).	No habitat	No
Lophochroa leadbeateri (*Cacatua leadbeateri*)	Major Mitchell's Cockatoo / Pink Cockatoo	V	~	Found across the arid and semi-arid inland, from south-western Queensland south to north-west Victoria, through most of South Australia, north into the south-west Northern Territory and across to the west coast between Shark Bay and about Jurien. In NSW it is found regularly as far east as about Bourke and Griffith, and sporadically further east than that .	Inhabits a wide range of tree and treeless inland habitats, always within easy reach of water. Feeds mostly on the ground, especially on the seeds of native and exotic melons and on the seeds of species of saltbush, wattles and cypress pines .	Moderate	Unlikely
Lophoictinia isura	Square-tailed Kite	V	~	Ranges along coastal and subcoastal areas from south-western to northern Australia, Queensland, NSW and Victoria. In NSW, scattered records of the species throughout the state indicate that it is a regular resident in the north, north-east and along the major west-flowing river systems.	Found in a variety of timbered habitats including dry woodlands and open forests. Shows a particular preference for timbered watercourses. In arid north-western NSW, has been observed in stony country with a ground cover of chenopods and grasses, open acacia scrub and patches of low open eucalypt woodland.	High	Known
Maccullochella peelii	Murray Cod	~	V	The Murray Cod remains patchily distributed throughout the Murray-Darling Basin, but has undergone an extensive decline in abundance (Koehn, Clunie, & Rylah, 2010).	Prefers deep holes in rivers with instream cover such as rocks, stumps, fallen trees or undercut banks (Lintermans, 2007).	No habitat	No
Macropus dorsalis	Black-striped Wallaby	E1	~	From the Townsville area in Queensland to northern NSW where it occurs on both sides of the Great Divide. On the North West Slopes of NSW it occurs to south of Narrabri. On the north coast it is confined to the upper catchments of the Clarence and Richmond Rivers.	Preferred habitat is characterised by dense woody or shrubby vegetation within three metres of the ground. This dense vegetation must occur near a more open, grassy area to provide suitable feeding habitat. On the North West Slopes, it is associated with dense vegetation, including brigalow, ooline and semi-evergreen vine thicket.	High	Known
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V	~	The Hooded Robin is, found across Australia, except for the driest deserts and the wetter coastal areas - northern and eastern coastal Queensland and Tasmania. However, it is common in few places, and rarely found on the coast. The south-eastern form (subspecies cucullata is found from Brisbane to Adelaide and throughout much of inland NSW, with the exception of the extreme north-west, where it is replaced by subsp. picata.	Associated with a wide range of Eucalypt woodlands, Acacia shrubland and open forests. In temperate woodlands, the species favours open areas adjoining large woodland blocks, with areas of dead timber and sparse shrub cover.	High	Known
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	~	This subspecies extends south from central Queensland, through NSW, Victoria into south eastern SA. In NSW it is widespread, with records from the tablelands and western slopes of the Great Dividing Range to the north-west and central-west plains and the Riverina. It is rarely recorded east of the Great Dividing Range, although regularly observed from the Richmond and Clarence River areas. It has also been recorded at a few scattered	Predominantly associated with box-ironbark association woodlands, especially Eucalyptus sideroxylon, *E. albens, E. microcarpa* and *E. tereticornis*. Also inhabits open forests of smooth-barked gums, stringybarks, ironbarks and tea-trees, and River Red Gum .	High	Potential

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
				sites in the Hunter, Central Coast and Illawarra regions.			
Merops ornatus	Rainbow Bee-eater	~	M, Mar	Distributed across much of mainland Australia, and occurs on several near-shore islands. It is not found in Tasmania, and is thinly distributed in the most arid regions of central and Western Australia (DotE, 2014c).	Occurs in open country, chiefly at suitable breeding places in areas of sandy or loamy soil: sand-ridges, riverbanks, road-cuttings, sand-pits, occasionally coastal cliffs.	High	Known
Miniopterus australis	Little Bentwing-bat	V	~	Occurs along the east coast and ranges of Australia from Cape York in Queensland to Wollongong in NSW.	Prefers well-timbered areas including rainforest, wet and dry sclerophyll forests, Melaleuca swamps and coastal forests (Churchill, 2008). This species shelters in a range of structures including culverts, drains, mines and caves. Relatively large areas of dense vegetation of either wet sclerophyll forest, rainforest or dense coastal banksia scrub are usually found adjacent to caves in which this species is found.	Low	Unlikely
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	~	Occur along the east and north-west coasts of Australia. There are capture records for the Kaputar Ranges to the north-east of the study area and previous records for west and south of the study area (OEH, 2016a).	Associated with a range of habitats: rainforest, wet and dry sclerophyll forest, monsoon forest, open woodland, paperbark forests and open grassland (Churchill, 2008). It forages above and below the tree canopy (Dwyer, 1981, 1995).	High	Known Detected from ultrasonic recordings only.
Monarcha melanopsis	Black-faced Monarch	~	M, Mar	Widespread in eastern Australia. In NSW, the species occurs around the slopes and tablelands inland to Armidale. It is rarely recorded further inland (DotE, 2014c).	Mainly occurs in rainforest ecosystems, including semi-deciduous vine-thickets, complex notophyll vine-forest, tropical (mesophyll) rainforest, subtropical (notophyll) rainforest, mesophyll (broadleaf) thicket/shrubland, warm temperate rainforest, dry (monsoon) rainforest and (occasionally) cool temperate rainforest (DotE, 2014c).	Low	Unlikely
Mormopterus lumsdenae (syn M. beccarii)	Beccari's Freetail-bat / Northern Freetail-bat	V	~	Widely distributed across northern Australia from Western Australia to Queensland, extending into north-east and north-central NSW. The only confirmed sighting in NSW is from Murwillumbah; however, calls have been detected from a few other locations in north east NSW. The study area is outside of its known distribution.	Occupies a wide range of habitats from rainforests to open forests and woodlands, often recorded along watercourses. It mainly roosts in tree-hollows but large roosts have been reported from house roofs. No information is currently available on possible habitat use in the Pilliga.	Moderate	Unlikely
Mormopterus norfolkensis	Eastern Freetail-bat	V	~	Found along the east coast from south Queensland to southern NSW. In NSW, records extend to the western slopes of the Great Dividing Range. The study area is considered outside their known range.	Prefers tall (greater than 20m) moist habitats, predominately roosting in Eucalypt tree hollows. It has also been found to roost under loose bark on trees and in man-made structures (Law, Herr, & Phillips, 2008).	Low	Unlikely
Myiagra cyanoleuca	Satin Flycatcher	~	M, Mar	In NSW, they are widespread on and east of the Great Divide and sparsely scattered on the western slopes, with very occasional records on the western plains (DotE, 2014c).	Inhabit heavily vegetated gullies in eucalypt-dominated forests and taller woodlands, and on migration, occur in coastal forests, woodlands, mangroves and drier woodlands and open forests (DotE, 2014c).	High	Known
Myotis macropus	Large-footed / Southern Myotis	V	~	Found in the coastal band from the north-west of Australia, across the top-end and south to western Victoria. It is rarely found more than 100 km inland, except along major rivers.	Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage. Forage over streams and	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
					pools catching insects and small fish by raking their feet across the water surface (Churchill, 2008).		
Neophema pulchella	Turquoise Parrot	V	~	Range extends from southern Queensland through to northern Victoria, from the coastal plains to the western slopes of the Great Dividing Range .	Steep rocky ridges and gullies, rolling hills, valleys and river flats and the plains of the Great Dividing Range compromise the topography inhabited by this species (Marchant & Higgins, 1993).	High	Known
Ninox connivens	Barking Owl	V	~	Found throughout continental Australia except for the central arid regions. Although common in parts of northern Australia, the species has declined greatly in southern Australia and now occurs in a wide but sparse distribution in NSW. Core populations exist on the western slopes and plains (especially the Pilliga) and in some northeast coastal and escarpment forests..	Associated with a variety of habitats such as savannah woodland, open eucalypt forests, wetland and Riverine forest. Habitat is typically dominated by Eucalypts (often Redgum species), but can also be dominated by Melaleuca species in the tropics. Roosts in dense shaded foliage in large trees such as *Casuarina cunninghamiana*, other *Casuarina* spp., *Allocasuarina* spp., *Eucalyptus* spp., *Angophora* spp., *Acaci*a spp. and other large trees.	High	Known
Ninox strenua	Powerful Owl	V	~	It is endemic to eastern and south-eastern Australia, mainly on the coastal side of the Great Dividing Range from Mackay to south-western Victoria. In NSW, it is widely distributed throughout the eastern forests from the coast inland to tablelands, with scattered, mostly historical records on the western slopes and plains. Now uncommon throughout its range where it occurs at low densities.	It inhabits a range of vegetation types, from woodland and open sclerophyll forest to tall open wet forest and rainforest. The species breeds and hunts in open or closed sclerophyll forest or woodlands and occasionally hunts in open habitats. It roosts by day in dense vegetation.	Low	Unlikely
Nyctophilus corbeni (syn. *Nyctophilus timoriensis* (South-eastern form))	South-eastern Long eared Bat / Corben's Long-eared Bat	V	V	The distribution of the south eastern form coincides approximately with the Murray Darling Basin with the Pilliga Scrub region being the distinct stronghold for this species.	Inhabits a variety of vegetation types including mallee, bulloke and box eucalypt dominated communities. However, it is more common in box/ironbark/cypress-pine vegetation that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland. Roosts in tree hollows, crevices and under loose bark.	High	Known
Oxyura australis	Blue-billed Duck	V	~	Endemic to south-eastern and south-western Australia. It is widespread in NSW, but most common in the southern Murray-Darling Basin area.	Prefers deep water in large permanent wetlands and swamps with dense aquatic vegetation. The species is completely aquatic, swimming low in the water along the edge of dense cover They are partly migratory, with short-distance movements between breeding swamps and over-wintering lakes with some long-distance dispersal to breed during spring and early summer .	Low	Potential
Pachycephala inornata	Gilbert's Whistler	V	~	Occurs across most of NSW's semi-arid and arid regions. The eastern population extends from the central NSW mallee (Yathong, Nombinnie and Round Hill NRs), south and east through the Cocoparra Range to Pomingalama Reserve (near Wagga Wagga) then north through the South West Slopes east as far as Cowra and Burrendong Dam, to the Goonoo reserves (with scattered records as far north as Pilliga).	Occurs in arid and semi-arid timbered habitats in mallee shrubland, and occasionally in box-ironbark woodlands, Cypress Pine and Belah woodlands and River Red Gum forests. Within mallee the species often occurs in association with an understorey of Spinifex and low shrubs of acacias, hakeas, sennas and grevilleas. In woodland habitats, the understorey contains areas of dense shrubbery .	Moderate	Potential
Petaurus australis	Yellow-bellied Glider	V	~	Found along the eastern coast to the western slopes of the Great Dividing Range, from southern Queensland, through NSW to Victoria .	Occurs in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils. Forest type preferences vary, with mixed coastal forests to dry escarpment forests in the north; moist coastal gullies and creek flats to tall montane forests in the south. Their den sites are in hollows of large trees.	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
Petaurus norfolcensis	Squirrel Glider	V	~	Widely though sparsely distributed in eastern Australia, from northern Queensland to western Victoria.	Associated with dry hardwood forest and woodlands (Menkhorst, Weavers, & Alexander, 1988; Quinn, 1995). Habitats typically include gum barked and high nectar producing species, including winter flower species (Menkhorst et al., 1988). The presence of hollow bearing eucalypts is a critical habitat value (Quinn, 1995).	High	Known
Petrogale penicillata	Brush-tailed Rock-wallaby	E1	V	Extends from south-east Queensland to the Grampians in western Victoria, roughly following the line of the Great Dividing Range. However the distribution across its original range has declined significantly in the west and south and has become more fragmented. In NSW they occur from the Queensland border in the north to the Shoalhaven in the south, with the population in the Warrumbungle Ranges being the western limit .	Occupies rocky areas (escarpments and outcrops) in a variety of habitats, typically north facing sites with numerous ledges, caves and crevices. They generally browse on vegetation in and adjacent to rocky areas, eating grasses and forbs as well as the foliage and fruits of shrubs and trees.	Low	Unlikely
Petroica boodang	Scarlet Robin	V	~	Found from SE Queensland to SE South Australia and also in Tasmania and SW Western Australia. In NSW, it occurs from the coast to the inland slopes. After breeding, some Scarlet Robins disperse to the lower valleys and plains of the tablelands and slopes. Some birds may appear as far west as the eastern edges of the inland plains in autumn and winter .	Primarily a resident in forests and woodlands, but some adults and young birds disperse to more open habitats after breeding. It lives in dry eucalypt forests and woodlands with an understorey that is usually open and grassy with few scattered shrubs. It can live in both mature and regrowth vegetation with an abundance of logs and fallen timber are an important component of its habitat.	High	Potential
Petroica phoenicea	Flame Robin	V	~	Endemic to southeast Australia, and ranges from near the Queensland border to SE South Australia and also in Tasmania. In NSW, it breeds in upland areas and in winter, many birds move to the inland slopes and plains. It is likely that there are two separate populations in NSW, one in the Northern Tablelands, and another ranging from the Central to Southern Tablelands .	Breeds in upland tall moist eucalypt forests and woodlands, often on ridges and slopes. The species prefers clearings or areas with open understoreys. The ground layer of the breeding habitat is dominated by native grasses and the shrub layer may be either sparse or dense. It occasionally occurs in temperate rainforest, and also in herbfields, heathlands, shrublands and sedgelands at high altitudes .	Low	Unlikely
Phaethon rubricauda	Red-tailed Tropicbird	V	Mar	This species of marine bird occurs throughout tropical and subtropical zones of the Indian and West Pacific Oceans. Breeding occurs on oceanic islands, with the largest breeding site occurring on Lord Howe Island. Vagrant birds occur in coastal water of NSW, and occasionally inland, particularly after storm events .	It is a marine species that breeds in coastal cliffs and under bushes in tropical Australia. It nests on cliffs of the northern hills and southern mountains on the main island at Lord Howe Island.	Low	Unlikely
Phascogale tapoatafa	Brush-tailed Phascogale	V	~	Patchy distribution around the coast of Australia. In NSW it is mainly found east of the Great Dividing Range although there are some historical records west of the divide through the central west of NSW.	Prefers dry sclerophyll open forest with sparse groundcover of herbs, grasses, shrubs or leaf litter, but can also inhabit heath, swamps, rainforest and wet sclerophyll forest. It nests and shelters in tree hollows, with entrances 2.5 - 4 cm wide and can use many hollows over a short time span .	Low	Unlikely
Phascolarctos cinereus	Koala	V	V	Fragmented distribution throughout eastern Australia from north-east Queensland to the Eyre Peninsula in South Australia. In NSW it mainly occurs on the central and north coasts with some populations in the west of the Great Dividing Range. A population is known in the Pilliga, predominantly in the west.	Associated with both wet and dry Eucalypt forest and woodland with a canopy cover of approximately 10 –70% (Reed, Lunney, & Walker, 1990), that contains acceptable eucalypt food trees. Primary feed tree in study area: *Eucalyptus camaldulensis*. Secondary food trees in the study area: *E. albens*, *E. blakelyi*, *E. chloroclada*, *E. conica*, *E. dealbata, E. dwyeri*, *E. macrocarpa*, *E. melliodora, E. pilligaensis* and *E. populnea*. Supplementary food tree in study area:	High	Likely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
					Eucalyptus macrorhyncha, *Callitris glaucophylla* is common, and is listed as a tree species used for daytime shelter.		
Plegadis falcinellus	Glossy Ibis	~	M, Mar	Recorded over much of NSW. Spring/summer breeding migrant to southern Murray-Darling region and Macquarie Marshes. Recorded previously at Yarrie Lake.	Edges of lakes and rivers, lagoons, flood-plains, wet meadows, swamps, reservoirs, sewage ponds, rice-fields and cultivated areas under irrigation. Occasionally estuaries, deltas, saltmarshes and coastal lagoons.	Moderate	Known
Polytelis anthopeplus monarchoides	Regent Parrot (Eastern Subspecies)	E1	V	Confined to the semi-arid interior of south-eastern mainland Australia. In NSW, it is confined to the southern Lower Western Region, mainly along the Murray River, from Kyalite, north west to Mallee Cliffs State Forest, and is also recorded near Wentworth and the Rufous River. Away from the Murray River, the subspecies is recorded at isolated localities including west of Moonlight Lake, Arumpo Station, and near Pooncarie	Primarily inhabits riparian or littoral *Eucalyptus camaldulensis* forests or woodlands and adjacent *E. largiflorens* woodlands. Nearby open mallee woodland or shrubland, usually with a ground cover of *Triodia* spp. (spinifex) or other grasses, supporting various eucalypts, as well as *Allocasuarina cristata*. They often occur in farmland, especially if the farmland supports remnant patches of woodland along roadsides or in paddocks. The subspecies seldom occurs in more extensively cleared areas	Moderate	Unlikely
Polytelis swainsonii	Superb Parrot	V	V	Found throughout eastern inland NSW. On the South-western Slopes their core breeding area is roughly bounded by Cowra and Yass in the east, and Grenfell, Cootamundra and Coolac in the west. Birds breeding in this region are mainly absent during winter, when they migrate north to the region of the upper Namoi and Gwydir Rivers. The other main breeding sites are in the Riverina along the corridors of the Murray, Edward and Murrumbidgee Rivers where birds are present all year round.	Inhabits box-gum woodland, Box-Cypress-pine and Boree Woodlands and River Red Gum Forest. Populations that migrate to the Namoi region in winter forage and roost in forests and woodlands dominated by *Callitris glaucophylla* and Box-gum. Previous sightings of Superb Parrot in the Pilliga Forest have been associated with drainage lines, foraging in Eucalypt canopy and grassland and flying through the landscape (OEH, 2016a).	Moderate	Potential
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V	~	The eastern subspecies (temporalis) occurs from Cape York south through QLD, NSW and Vic and formerly to the south east of SA. This subspecies also occurs in the Trans-Fly Region in southern New Guinea. In NSW, the eastern sub-species occur on the western slopes of the Great Dividing Range, and on the western plains reaching as far as Louth and Balranald. It also occurs in woodlands in the Hunter Valley and in some locations on the north coast.	Found in open woodlands dominated by mature eucalypts with regenerating trees, tall shrubs, and an intact ground cover of grass and forbs .This species avoids very wet areas (Blakers, Davies, & Reilly, 1984). It favours Box-gum woodlands on the slopes and Box-cypress and open Box woodlands on alluvial plains.	High	Known
Pseudomys pilligaensis	Pilliga Mouse	V	V	Distribution restricted to the Pilliga region of New South Wales. Fox and Briscoe first described this species in 1980 (Fox & Briscoe, 1980). There is still some conjecture on its specific status.	Occurs in Pilliga Scrub on an isolated area of low-nutrient deep sand. They seem to prefer areas with a high species diversity and dense low shrub layer.	High	Known
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	Found within 200 km of the eastern coast of Australia, from Bundaberg in Queensland to Melbourne in Victoria.	This species roosts in camps generally located within 20 km of a regular food source and are commonly found in gullies, close to water and in vegetation with a dense canopy. This species is known to forage in areas supporting subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps on the nectar and pollen of native trees, in particular eucalypts, melaleucas and banksias.	Moderate	Unlikely
Rhipidura rufifrons	Rufous Fantail	~	M, Mar	Occurs in coastal and near coastal districts of northern and eastern Australia (DotE, 2014c). It has	Mainly inhabits wet sclerophyll forests, often in gullies. When in migratory movement are more	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
				the potential to occur further inland west of the great divide when on summer migratory movement.	likely to occur in dry sclerophyll forests, woodland and more open habitats (DotE, 2014c).		
Rostratula australis (syn. *Rostratula benghalensis australis*)	Australian Painted Snipe	E1	E, Mar	Recorded at wetlands in all states of Australia. It is most common in eastern Australia, where it has been recorded at scattered locations throughout much of Queensland, NSW, Victoria and south-eastern South Australia.	Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	Low	Potential
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	~	Wide-ranging species found across northern and eastern Australia. In the most southerly part of its range - most of Victoria, south-western NSW and adjacent South Australia - it is a rare visitor in late summer and autumn. There are scattered records of this species across the New England Tablelands and North West Slopes.	Found in almost all habitats, from wet and dry sclerophyll forest, open woodland, open country, mallee, rainforests, heathland and waterbodies (Churchill, 2008). It roosts in tree hollows and may also use caves.	High	Known
Scoteanax rueppellii	Greater Broad-nosed Bat	V	~	Found along both sides of the great divide in Queensland and NSW with a record from the Kaputar ranges area to the north of the study area.	Occurs in moist gullies in mature coastal forest, rainforest open woodland, swamp forests cleared paddocks with remnant trees and tree-lined creeks in open areas (Churchill, 2008). Predominately a tree-hollow dependant species but has also been found in roofs of old buildings.	Moderate	Unlikely
Sminthopsis macroura	Stripe-faced Dunnart	V	~	Throughout much of inland central and northern Australia, extending into central and northern NSW, western Queensland, Northern Territory, South Australia and Western Australia. They are rare on the NSW Central West Slopes and North West Slopes with the most easterly records of recent times located around Dubbo, Coonabarabran, Warialda and Ashford.	Native dry grasslands and low dry shrublands, often along drainage lines. During periods of hot weather they shelter in cracks in the soil, in grass tussocks or under rocks and logs .	Low	Potential
Stagonopleura guttata	Diamond Firetail	V	~	Endemic to south-eastern Australia, extending from central QLD to the Eyre Peninsula in SA. It is widely distributed in NSW, with a number of records from the Northern, Central and Southern Tablelands, the Northern, Central and South Western Slopes and the North West Plains and Riverina.	Typically found in grassy eucalypt woodlands, but also occurs in open forest, mallee, Natural Temperate Grassland, and in secondary grassland derived from other communities. It is often found in riparian areas and sometimes in lightly wooded farmland. Appears to be sedentary, though some populations move locally, especially those in the south.	High	Known
Stictonetta naevosa	Freckled Duck	V	~	Found primarily in south-eastern and south-western Australia, occurring as a vagrant elsewhere. It breeds in large temporary swamps created by floods in the Bulloo and Lake Eyre basins and the Murray-Darling system, particularly along the Paroo and Lachlan Rivers, and other rivers within the Riverina .	Prefers permanent freshwater swamps and creeks with heavy growth of Typha, Lignum or Tea-tree. During drier times they move from ephemeral breeding swamps to more permanent waters such as lakes, reservoirs, farm dams and sewage ponds.	Low	Potential
Tyto longimembris	Eastern Grass Owl	V	~	Recorded occasionally in all mainland states of Australia but are most common in northern and north-eastern Australia. In NSW they are more likely to be resident in the north-east. Eastern Grass Owl numbers can fluctuate greatly, increasing especially during rodent plagues .	Found in areas of tall grass, including grass tussocks, in swampy areas, grassy plains, swampy heath, and in cane grass or sedges on flood plains.	Low	Unlikely
Tyto novaehollandiae	Masked Owl	V	~	Extends from the coast where it is most abundant to the western plains. Overall records for this species fall within approximately 90% of NSW, excluding the most arid north-western corner. There is no seasonal variation in its distribution.	Associated with forest with sparse, open, understorey, typically dry sclerophyll forest and woodland and especially the ecotone between wet and dry forest, and non-forest habitat. The species is known to utilise forest margins and isolated stands of trees within agricultural land	High	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution (OEH, 2016b)	Habitat (OEH, 2016b)	Availability of habitat in the study area	Likelihood of occurrence in the study area
					and heavily disturbed forest where its prey of small and medium sized mammals can be readily obtained (Kavanagh & Peake, 1993).		
Uvidicolus sphyrurus (syn. *Underwoodisaurus sphyrurus*)	Border Thick-tailed Gecko	V	V	Found only on the tablelands and slopes of northern NSW and southern Queensland, reaching south to Tamworth and west to Moree Most common in the granite country of the New England Tablelands .	Found in rocky hills with dry open eucalypt forest or woodland Favours forest and woodland areas with boulders, rock slabs, fallen timber and deep leaf litter .	Low	Unlikely
Vespadelus troughtoni	Eastern Cave Bat	V	~	Found in a broad band on both sides of the Great Dividing Range from Cape York to Kempsey, with records from the New England Tablelands and the upper north coast of NSW. The western limit appears to be the Warrumbungle Range, and there is a single record from southern NSW, east of the ACT .	The species inhabits tropical mixed woodland and wet sclerophyll forest on the coast and the dividing range but extend into the drier forest of the western slopes and inland areas. It has been found roosting in sandstone overhand caves, boulder piles, mine tunnels and occasionally in buildings (Churchill, 2008).	High	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
FLORA							
Acacia jucunda	Yetman Wattle	E1	~	Found in the Yetman district near the Queensland border on the North West Slopes of NSW. It also occurs in Queensland where it is reasonably common.	Mainly restricted to the dry eucalypt forests or woodlands on sandy to sandy-loam soils. It is associated with other species in NSW including, *Acacia polybotrya* (Western Silver Wattle) and *Callitris endlicheri* (Black Cypress Pine). The species is known to occur within the Border Rivers – Gwydir CMA area but mostly restricted to the Yetman area.	Low	Unlikely
Bertya opponens	Coolabah Bertya	V	V	Known from scattered sites in NSW including Coolabah, south of Narrabri on the North West Slopes (including Jacks Creek State Forest), Cobar and the North Coast.	Ranges from stony mallee ridges and cypress pine forest on red soils.	Moderate	Known
Boronia granitica	Granite Boronia	V	E	Known from scattered localities on the New England Tablelands and North West Slopes north from the Armidale area to the Stanthorpe district in southern Queensland.	Grows amongst granite outcrops, often in rock crevices, north from Inverell district.	No habitat	No

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Cadellia pentastylis	Ooline	V	V	Occurs along the western edge of the North West Slopes from north of Gunnedah to west of Tenterfield with some records from in Queensland. The natural range of Ooline is from 24ºS to 30ºS in the 500 to 750 mm per annum rainfall belt.	Occurs in low- to medium-nutrient soils of sandy clay or clayey consistencies, with a typical soil profile having a sandy loam surface layer, grading from a light clay to a medium clay with depth.	Low	Unlikely
Cyperus conicus	A sedge	E1	~	Occurs rarely in the Pilliga area of NSW and is also found in Victoria, Qld, the NT and WA	Grows in open woodland on sandy soil. In central Australia, it grows near waterholes and on the banks of streams in sandy soils. In Qld the species is usually found on heavy soils. It has been recorded from Callitris forest in the Pilliga area, growing in sandy soil with *Cyperus gracilis*, *C. squarrosus* and *C. fulvus*.	Moderate	Unlikely
Desmodium campylocaulon	Creeping Tick-Trefoil	E1	~	Occurs chiefly in the Collarenebri and Moree districts in the north-western plains of NSW. Also occurs in the NT and Darling Downs district of south-eastern Queensland	In NSW the species grows on cracking black soils in the Narrabri, Moree and Walgett local government areas. It is associated with other species including *Acacia harpophylla*, *Astrebla pectinata* and *Sorghum*, *Dichanthium* and *Panicum* species. It flowers summer and autumn	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Dichanthium setosum	Bluegrass	V	V	New England Tablelands, North West Slopes and Plains and the Central Western Slopes of NSW, as well as in Queensland and Western Australia.	Associated with heavy basaltic black soils. Often found in moderately disturbed areas such as cleared woodland, grassy roadside remnants and highly disturbed pasture.	Low	Unlikely
Digitaria porrecta	Finger Panic Grass	E1	Delisted	Occurs in NSW and Queensland. In NSW it is found on the North West Slopes and Plains, from near Moree south to Tambar Springs and from Tamworth to Coonabarabran.	Native grassland, woodlands or open forest with a grassy understorey, on richer soils.	Low	Unlikely
Diuris tricolor	Painted Diuris	V	~	Sporadically distributed on the western slopes of NSW, extending from south of Narrandera all the way to the far north of NSW.	Grows in sclerophyll forest among grass, often with native Cypress Pine (*Callitris spp.*). It is found in sandy soils, either on flats or small rises. Also recorded from a red earth soil in a Bimble Box community in western NSW. Disturbance regimes are not known, although the species is usually recorded from disturbed habitats.	High	Known
Haloragis exalata subsp. *velutina*	Tall Velvet Sea-berry	V	V	Disjunctly distributed in the central coast, south coast and north-western slopes botanical subdivisions of NSW	Protected and shaded damp situations in riparian habitats.	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Homopholis belsonii	Belson's Panic	E1	V	North from the Warialda district and into Queensland	Habitat and ecology poorly known. Grows in dry woodland (e.g. Belah) on poor soils.	Low	Unlikely
Lepidium aschersonii	Spiny Peppercress	V	V	Not widespread, occurring in the marginal central-western slopes and north-western plains regions of NSW (and potentially the south western plains). A several populations recorded at Narrabri. Also known from the West Wyalong, Barmedman and Temora areas.	Found on ridges of gilgai clays dominated by *Acacia harpophylla* (Brigalow), with *Austrodanthonia* and/or *Austrostipa* species in the understorey. The species grows as a component of the ground flora, in grey loamy clays. Vegetation structure varies from open to dense Brigalow, with sparse grassy understorey and occasional heavy litter.	Moderate	Known
Lepidium monoplocoides	Winged Peppercress	E1	E	Widespread in the semi-arid western plains region of NSW. Recorded in previous ELA survey in Western Pilliga.	Known to occur on seasonally moist to waterlogged sites, on heavy fertile soils. In W Pilliga, it was found in White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion vegetation and associated with gilgais.	Moderate	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Monotaxis macrophylla	Large-leafed Monotaxis	E1	~	Known from several highly disjunct populations in NSW: eastern edge of Deua NP (west of Moruya), Bemboka portion of South East Forests National Park, Cobar area (Hermitage Plains), the Tenterfield area, and Woodenbong (near the Queensland border). It is also in Queensland.	Grows on rocky ridges and hillsides. There is a great diversity in the associated vegetation within NSW (less though in Queensland), encompassing coastal heath, arid shrubland, forests and montane heath from almost sea level to 1300 m altitude.	Moderate	Unlikely
Myriophyllum implicatum		CE	~	Previously thought to be extinct in NSW; however the plant was recently discovered in the Pilliga National Park, south of Narrabri.	Occurs in moist situations, extending away from fresh water. A recent population was found in NSW in a large open partly inundated gilgai depression on cracking clay soil.	Low	Known
Philotheca ericifolia		~	V	Upper Hunter Valley and Pilliga to Peak Hill district	Grows chiefly in dry sclerophyll forest and heath on damp sandy flats and gullies	Low	Unlikely
Platyzoma microphyllum	Braid Fern	E1	~	Species records exist in NSW only in the Yetman district. However, the species is widespread across northern Australia, from WA to the NT, eastern Qld and just into central-northern NSW.	Grows in sandy or swampy soils, or in clay soils adjacent to streams and lagoons and subject to periodic flooding. It has been recorded in NSW at Bruxner Highway growing as one localised patch in deep sandy soil, with *Leptospermum* species, *Brachyloma daphnoides* and *Lomandra* species.	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Polygala linariifolia	Native Milkwort	E1	~	Found north from Copeton Dam and the Warialda area to southern QLD; also found on the NSW north coast near Casino and Kyogle, and there is an isolated population in far western NSW near Weebah Gate, west of Hungerford. This species also occurs in Western Australia.	Occurs in sandy soils in dry eucalypt forest and woodland with a sparse understorey. The species has been recorded from the Inverell and Torrington districts growing in dark sandy loam on granite in shrubby forest of *Eucalyptus caleyi, Eucalyptus dealbata* and *Callitris*, and in yellow podsolic soil on granite in layered open forest.	High	Known
Pomaderris queenslandica	Scant Pomaderris	E1	~	Records are widely scattered, but not common in north-east NSW and in Queensland. It is only known from a few locations on the New England Tablelands and North West Slopes, including near Torrington and Coolatai, and also from several locations on the NSW north coast.	Found in moist eucalypt forest or sheltered woodlands with a shrubby understorey, and occasionally along creeks.	Moderate	Known

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Prasophyllum sp. *Wybong* (C.Phelps ORG 5269) *Listed as Prasophyllum petilum as Endangered in EPBC Act and Endangered in TSC Act*	a leek-orchid Listed as Tarengo Leek Orchid	~	CE	Endemic to NSW. It is known from seven populations in eastern NSW near Ilford, Premer, Muswellbrook, Wybong, Yeoval, Inverell and Tenterfield	Known to occur in open eucalypt woodland and grassland	Low	Unlikely
Pterostylis cobarensis	Greenhood Orchid	V	~	Known chiefly from the Nyngan-Cobar-Bourke district in the far western plains of New South Wales. Recorded districts include Narrabri, Nyngan, Cobar, Nymagee, Mt Gundabooka, Mt Grenfell and Mutawintji National Park. There are also records from the Darling Downs district of Queensland.	Found in Eucalypt woodlands, open mallee or *Callitris* shrublands on low stony ridges and slopes in skeletal sandy-loam soils.	High	Known
Pultenaea setulosa	Stony Bush-pea	~	V	Slopes and tablelands of NSW	Dry sclerophyll forest	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Commersonia procumbens *(Listed as Androcalva procumbens in EPBC Act)*		V	V	Endemic to NSW and mainly confined to the Dubbo-Mendooran-Gilgandra region, but also in the Pilliga and Nymagee areas.	Grows in sandy sites, often along roadsides. Recorded in *Eucalyptus dealbata* and *E. sideroxylon* communities, *Melaleuca uncinata* scrub, under mallee eucalypts with a *Calytrix tetragona* understorey, and in a recently burnt Ironbark and *Callitris* area. It also occurs in *E. fibrosa* subsp. *nubila, E. dealbata, E. albens* and *Callitris glaucophylla* woodlands north of Dubbo.	High	Known
Sida rohlenae	Shrub Sida	E1	~	Has a limited distribution in QLD, the NT, SA and WA. In NSW it has been recorded south of Enngonia, south of Bourke and north-west of Coonamble	Occurs in flood-out areas, creek banks and at the base of rocky hills. NSW specimens have been found along roadsides in hard red loam to sandy-loam soils.	Low	Unlikely
Swainsona murrayana	Slender Darling Pea	V	V	Found throughout NSW. It has been recorded in the Jerilderie and Deniliquin areas of the southern Riverine plain, the Hay plain as far north as Willandra National Park, near Broken Hill and in various localities between Dubbo and Moree.	Known from clay-based soils, ranging from grey, red and brown cracking clays to red-brown earths and loams. It grows in a variety of vegetation types including bladder saltbush, black box and grassland communities on level plains, floodplains and depressions and is often found with *Maireana* species.	Low	Unlikely

Scientific name	Common name	TSC Act	EPBC Act	Distribution	Habitat	Availability of habitat in the study area	Likelihood of occurrence in the study area
Thesium australe	Austral Toadflax	V	V	Small populations are scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia.	Occurs in grassland or grassy woodland and often found in damp sites in association with *Themeda australis* (Kangaroo Grass).	Low	Unlikely
Tylophora linearis	-	V	E	Found in the Barraba, Mendooran, Temora and West Wyalong districts in the northern and central western slopes of NSW.	Grows in dry scrub and open forest. Recorded from low-altitude sedimentary flats in dry woodlands of *Eucalyptus fibrosa*, *E. sideroxylon*, *E. albens*, *Callitris endlicheri*, *C. glaucophylla* and *Allocasuarina luehmannii*.	High	Known

Threatened ecological community	TSC Act	EPBC Act	Description	Availability of habitat in the study area	Likelihood of occurrence in the study area
ENDANGERED ECOLOGICAL COMMUNITIES					
TSC: Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions EPBC: Brigalow (*Acacia harpophylla* dominant and co-dominant)	E	E	The ecological community is a low woodland or forest community dominated by *Acacia harpophylla* (Brigalow), with pockets of *Casuarina cristata* (Belah) and *Eucalyptus populnea* subsp. *bimbil* (Poplar Box). The canopy tends to be quite dense and the understorey and ground cover are only sparse. It is found in the Brigalow Belt South Bioregion in NSW and as isolated occurrences in the Darling Riverine Plains and Nandewar Bioregions.	Low	Known
Cadellia pentastylis (Ooline) community in the Nandewar and Brigalow Belt South Bioregions	E	~	The Ooline community is an unusual and distinctive forest community with the canopy dominated by the tree *Cadellia pentastylis* (Ooline). Other canopy species include *Eucalyptus albens* (White Box), *E. beyeriana* and *E. melanophloia*, *E. chloroclada* (Dirty Gum), *E. pilligaensis* (Narrow-leaved Grey Box), *E. viridis* (Green Mallee) and *Callitris glaucophylla* (White Cypress Pine). The understorey is made up of a range of shrubs such as wattles and grasses. It is now known from only seven main locations on the North West Slopes in NSW, between Narrabri and the Queensland border, and also in Queensland.	Low	Unlikely
Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions	E	~	This was previously an open forest community of flora and fauna that may now exist as woodland or as remnant trees. Characteristic tree species are Carbeen (Corymbia tessellaris) and White Cypress Pine (Callitris glaucophylla). Associated trees include Corymbia dolichocarpa, Eucalyptus populnea, E. camaldulensis, Casuarina cristata and Allocasuarina luehmannii.	Low	Known
TSC: Coolibah-Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregion EPBC: Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	E	E	Represents occurrences of one type of semi-arid to humid subtropical woodland where *Eucalyptus coolabah* subsp. *coolabah* (Coolibah) and/or *Eucalyptus largiflorens* (Black Box) are the dominant canopy species and where the understorey tends to be grassy. The structure of the community may vary from tall riparian woodlands to very open 'savannah like' grassy woodlands with a sparse midstorey of shrubs and saplings. The ecological community is associated with the floodplains and drainage areas of the Darling Riverine Plains and the Brigalow Belt South bioregions.	Low	Unlikely

Threatened ecological community	TSC Act	EPBC Act	Description	Availability of habitat in the study area	Likelihood of occurrence in the study area
TSC: Myall Woodlands in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions EPBC: Weeping Myall Woodlands	E	E	Occurs on red-brown earths and heavy textured grey and brown alluvial soils where annual rainfall is in the range 375 and 500 mm. The structure can varies from low woodland and low open woodland to low sparse woodland or open shrubland. The tree layer grows up to a height of about 10 metres and invariably includes *Acacia pendula* (Weeping Myall or Boree) as one of the dominant species or the only tree species present. The understorey includes an open layer of chenopod shrubs and other woody plant species and an open to continuous groundcover of grasses and herbs. The shrub stratum may have been reduced by clearing or heavy grazing. It is scattered across the eastern parts of alluvial plains of the Murray-Darling river system.	Low	Known
TSC: White Box Yellow Box Blakely's Red Gum Woodland EPBC: White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	E	CE	The community has an overstorey dominated, or was once dominated by *Eucalyptus albens* (White Box), *E. melliodora* (Yellow Box) or *E. blakelyi* (Blakely's Red Gum) trees. It is characterised by a species-rich understorey of native tussock grasses, herbs and forbs. In the Nandewar Bioregion, *E. microcarpa* or *E. moluccana* may also be dominant or co-dominant. The tree-cover is generally discontinuous and consists of widely-spaced trees of medium height in which the canopies are clearly separated. The shrub layer can be non-existent. In NSW the community is found from the Queensland border in the north, to the Victorian border in the south along the tablelands and western slopes areas.	Low	Unlikely
Fuzzy Box Woodland on alluvial soils of the south western slopes, Darling Riverine Plains and Brigalow Belt South bioregions	E	~	The community is a tall woodland or open forest usually dominated by *Eucalyptus conica* (Fuzzy Box), which often grows with *E. microcarpa* (Inland Grey Box), *E. melliodora* (Yellow Box) or *Brachychiton populneus* (Kurrajong). *Allocasuarina luehmannii* (Buloke) is common in places. Shrubs are generally sparse and the ground cover moderately dense, but this can change with the season. It is found on the alluvial soils of the South West Slopes, Brigalow Belt South and Darling Riverine Plains Bioregions (mainly in the Dubbo-Narromine-Parkes-Forbes area).	Moderate	Known

Threatened ecological community	TSC Act	EPBC Act	Description	Availability of habitat in the study area	Likelihood of occurrence in the study area
TSC: Inland Grey Box Woodland in the Riverina, NSW south western slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions EPBC: Grey Box (*Eucalyptus microcarpa*) Grassy Woodlands and Derived Native Grasslands of south-eastern Australia	E	E	The community is a woodland dominated by *Eucalyptus microcarpa* (Inland Grey Box). It is often found in association with *E. populnea* subsp. *bimbil*, *Callitris glaucophylla* (White Cypress Pine), *Brachychiton populneus* (Kurrajong), *Allocasuarina luehmannii* (Bulloak) or *E. melliodora* (Yellow Box), and sometimes with *E. albens* (White Box). It occurs in landscapes of low-relief such as flat to undulating plains, low slopes and rises and, to a lesser extent, drainage depressions and flats. The ecological community may extend to more elevated hillslopes on the fringes of its range where it intergrades with other woodland or dry sclerophyll forest communities. In NSW the community principally occurs within the Riverina and South West Slopes Bioregions and is also found in portions of the Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions.	Low	Unlikely
TSC: Native Vegetation on Cracking Clay Soils of the Liverpool Plains EPBC: Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland	E	CE	The ecological community is mainly a native grassland community containing a range of small forb and herb species, but can be found with scattered / patchy shrubs and trees. The main grass species include *Austrostipa aristiglumis* (Plains Grass), *Dichanthium sericeum* (Queensland Bluegrass) and *Panicum queenslandicum* (Coolibah Grass). It occurs on flat to low slopes, of no more than 5 percent (or less than 1 degree) inclination. As slope increases, grassy woodlands dominated by trees such as *Acacia pendula* (Weeping Myall), *Eucalyptus coolabah* (Coolabah), *E. populnea* (Poplar Box) or *E. melliodora* (Yellow Box) occur. The ground layer component of these woodlands may be similar to the grassland but the soils will not be the same cracking clays as on the plains.	Low	Unlikely
TSC: Semi-evergreen Vine Thicket in the Brigalow Belt South and Nandewar Bioregions EPBC: Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	E	E	The community is a low, dense form of dry rainforest generally less than 10 m high, made up of vines and rainforest trees as well as some shrubs. The main canopy is dominated by rainforest species such as *Cassine australis* var. *angustifolia* (Red Olive Plum), *Geijera parvifolia* (Wilga), *Notelaea microcarpa* var. *microcarpa* (Native Olive) and *Ehretia membranifolia* (Peach Bush), with taller eucalypts and cypress pines from surrounding woodland vegetation emerging above the main canopy. *Carissa ovata* (Currant Bush) is often present and typical vines include *Parsonsia eucalyptophylla* (Gargaloo) and *Pandorea pandorana* (Wonga Vine). It has a scattered distribution near Gunnedah, Barraba, Bingara and north of Warialda on the NSW North West Slopes and Plains, and also in Queensland.	Low	Unlikely

Threatened ecological community	TSC Act	EPBC Act	Description	Availability of habitat in the study area	Likelihood of occurrence in the study area
Marsh Club-rush sedgeland in the Darling Riverine Plains Bioregion	CE	~	The community is dominated by *Bolboschoenus fluviatilis* (Marsh Club-rush), which forms dense stands up to 2 m tall. The community is further characterised by an understorey including *Carex appressa* (Tussock Sedge), *Eleocharis plana* (Ribbed Spike Rush), *Lachnagrostis filiformis* (Blown Grass), *Paspalum distichum* (Water Couch) and *Ranunculus undosus* (Swamp Buttercup). It is distinguished from other surrounding communities by a lack of trees and the dominance of *Bolboschoenus fluviatilis* (generally over 40% of the vegetation cover) although the structure may vary depending on past disturbance. The community is associated with grey clay soils usually with a surface layer of organic matter several centimetres thick. The community has a very fragmented distribution and is mainly restricted to the Gwydir wetlands but may occur elsewhere in the Darling Riverine Plains Bioregion.	Low	Unlikely

Appendix J: Assessment of significance under the EPA Act

The following appendix provides an assessment of the potential significance of impacts from the project on biodiversity values listed under the TSC Act. The biodiversity values considered relevant to this assessment are identified in **Section 6.1** of this report.

The assessment of impact has been conducted with consideration to the assessment of significance criteria from the TSC Act Threatened species assessment guidelines: the assessment of significance (DECC 2007), as outlined in the text box below:

7-Part Test Assessment of Significance

1. *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*
2. *In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.*
3. *In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:*
    I. *Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or*
    II. *Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,*
4. *In relation to the habitat of a threatened species, population or ecological community:*
    I. *the extent to which habitat is likely to be removed or modified as a result of the action proposed, and*
    II. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and*
    III. *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*
5. *Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).*
6. *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*
7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process*.

The following definitions are have been used in the assessment (DECC 2007):

- Composition: both the plant and animal species present, and the physical structure of the ecological community. Note that while many ecological communities are identified primarily by their vascular plant composition, an ecological community consists of all plants and animals as defined under the TSC and FM Acts that occur in that ecological community.
- Critical habitat: refers only to those areas of land listed on the registers (OEH 2013; DPI 2014).

- Extent: the physical area removed and/or to the compositional components of the habitat and the degree to which each is affected.
- Habitat: the area occupied, or periodically or occasionally occupied, by threatened species, population or ecological community and includes all the different aspects (both biotic and abiotic) used by species during the different stages of their life cycles.
- Importance: related to the stages of the species' life cycles and how reproductive success may be affected.
- Life cycle: the series or stages of reproduction, growth, development, ageing and death of an organism.
- Local occurrence: the ecological community that occurs within the study area. However the local occurrence may include adjacent areas if the ecological community on the study area forms part of a larger contiguous area of that ecological community and the movement of individuals and exchange of genetic material across the boundary of the study area can be clearly demonstrated.
- Local population (flora): those individuals occurring in the study area or the cluster of individuals that extend into habitat adjoining and contiguous with the study area that could reasonably be expected to be cross-pollinating with those in the study area.
- Local population (migratory or nomadic fauna): those individuals that are likely to occur in the study area from time to time.
- Location population (fauna): those individuals known or likely to occur in the study area, as well as individuals occurring in adjoining areas (contiguous or otherwise) that are known or likely to utilise habitats in the study area.
- Risk of extinction (community): the likelihood that the local occurrence of the ecological community will become extinct either in the short-term or in the long-term as a result of direct or indirect impacts on the ecological community, and includes changes to ecological function.
- Risk of extinction (species): the likelihood that the local population will become extinct either in the short-term or in the long-term as a result of direct or indirect impacts on the viability of that population.
- Viable: the capacity to successfully complete each stage of the life cycle under normal conditions. The populations in the study area of all species in this assessment are considered viable, even if the species is only potentially occurring in the study area.

Fauna species have been grouped for the assessment with similar species that share habitat, lifecycle or other ecological characteristics and are likely to be impacted in a similar manner.

Species and ecological communities assessed under the TSC act include:

Ecological Communities

- Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions
- Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions
- Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions

- Myall Woodlands in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions

Flora

- *Bertya opponens* (Coolabah Bertya)
- *Diuris tricolor* (Painted Diuris)
- *Lepidium aschersonii* (Spiny Peppercress)
- *Lepidium monoplocoides* (Winged Peppercress)
- *Myriophyllum implicatum*
- *Polygala linariifolia* (Native Milkwort)
- *Pomaderris queenslandica* (Scant Pomaderris)
- *Pterostylis cobarensis* (Greenhood Orchid)
- *Rulingia procumbens*
- *Tylophora linearis*

Birds

- Parrots:
    - *Calyptorhynchus lathami* (Glossy Black-Cockatoo), *Glossopsitta pusilla* (Little Lorikeet) and *Neophema pulchella* (Turquoise Parrot)
- Parrots – winter migratory:
    - *Lathamus discolor* (Swift Parrot) and *Polytelis swainsonii* (Superb Parrot)
- Owls:
    - *Ninox connivens* (Barking Owl) and *Tyto novaehollandiae* (Masked Owl)
- Birds of prey:
    - *Circus assimilis* (Spotted Harrier), *Falco hypoleucos* (Grey Falcon), *Falco subniger* (Black Falcon), *Hamirostra melanosternon* (Black-breasted Buzzard), *Hieraaetus morphnoides* (Little Eagle), and *Lophoictinia isura* (Square-tailed Kite)
- Woodland birds – large ground foraging:
    - *Ardeotis australis* (Australian Bustard) and *Burhinus grallarius* (Bush Stone-curlew)
- Woodland birds – ground and mid-storey foraging (passerines):
    - *Artamus cyanopterus cyanopterus* (Dusky Woodswallow), *Chthonicola sagittata* (Speckled Warbler), *Daphoenositta chrysoptera* (Varied Sittella), *Melanodryas cucullata cucullata* (Hooded Robin), *Pachycephala inornata*

(Gilbert's Whistler), *Pomatostomus temporalis temporalis* (Grey-crowned Babbler), *Petroica boodang* (Scarlet Robin) and *Stagonopleura guttata* (Diamond Firetail).

- Woodland birds – canopy foraging (excluding parrots):
  - *Anthochaera phrygia* (Regent Honeyeater), *Grantiella picta* (Painted Honeyeater) and *Melithreptus gularis gularis* (Black-chinned Honeyeater).

- Wetland or aquatic birds:
  - *Anseranas semipalmata* (Magpie Goose), *Botaurus poiciloptilus* (Australasian Bittern), *Ephippiorhynchus asiaticus* (Black-necked Stork), *Grus rubicunda* (Brolga), *Oxyura australis* (Blue-billed Duck), *Rostratula australis* (Australian Painted Snipe) and *Stictonetta naevosa* (Freckled Duck)

Mammals

- *Aepyprymnus rufescens* (Rufous Bettong)
- *Dasyurus maculatus* (Spotted-tailed Quoll)
- *Macropus dorsalis* (Black-striped Wallaby)
- *Phascolarctos cinereus* (Koala)
- *Pseudomys pilligaensis* (Pilliga Mouse)
- *Sminthopsis macroura* (Stripe-faced Dunnart)
- Arboreal hollow-dependent mammals:
  - *Cercartetus nanus* (Eastern Pygmy Possum) and *Petaurus norfolcensis* (Squirrel Glider)
- Predominantly tree-roosting bats:
  - *Chalinolobus picatus* (Little Pied Bat), *Nyctophilus corbeni* (South-eastern Long-eared Bat) and *Saccolaimus flaviventris* (Yellow-bellied Sheathtail-bat)
- Predominantly cave-roosting bats:
  - *Chalinolobus dwyeri* (Large-eared Pied Bat), *Miniopterus schreibersii oceanensis* (Eastern Bentwing-bat) and *Vespadelus troughtoni* (Eastern Cave Bat).

Reptiles

- *Hoplocephalus bitorquatus* (Pale-headed Snake)

1.2 Ecological communities

Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions

The community largely occurs on heavy clay soils on the North West Slopes and Plains and Darling River Plains in NSW, and also occurs in Queensland. It is found in the Brigalow Belt South Bioregion and as isolated occurrences in the Darling Riverine Plains and Nandewar Bioregions. This community is known to occur within the north of the study area, predominantly in remnant patches in Brigalow State Conservation Area and along roadsides. It also occurs in Brigalow Nature Reserve which is excluded from the study area.

The community comprises low woodland or forest dominated by *Acacia harpophylla* (Brigalow), with pockets of *Casuarina cristata* (Belah) and *Eucalyptus populnea* subsp. *bimbil* (Poplar Box). There is generally a dense canopy and a sparse understorey and ground layer (OEH 2016b).

Within the study area, approximately 2,467.97 ha of this community has been mapped and approximately 8,704.19 ha of this community has been mapped in the study region. An upper limit of 19.30 ha would be directly impacted which equates to 0.78% directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 3.90 ha which would combine to impact a total of 0.94% in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

The project is unlikely to place the local occurrence of this ecological community at risk of extinction by having an adverse effect on the extent or by substantially and adversely modifying the composition.

I. The extent of this community is confined to the north of the study area and over 99%

of this community would not be removed or indirectly impacted. The geographical extent would not be contracted or significantly intersected. Using the ecological scouting framework, areas of this community would be avoided where possible which would minimise the extent directly and indirectly impacted.

II. The composition of this community may be modified in areas that are indirectly impacted. The indirect impact would be comparable to removing 0.16% of this community in the study area. Over 99% of this community will not be directly or indirectly impacted and hence would not be adversely modified in composition. Vegetation clearing would be documented to ensure that clearing limits are not surpassed.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 19.30 ha of this community, which constitutes approximately 0.78% of this community in the study area. The project has potential to modify additional area of this community as a result of indirect impacts. The reduction in vegetation structure and quality would be comparable to the loss of a further 3.90 ha of this community. The direct and indirect impact on this community would constitute a total impact of approximately 0.94% of this community in the study area.

II. Additional fragmentation of this community would occur as a result of the project. It is likely that additional patches of this community would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. This community would not be intersected by the 30 m Bibblewindi to Leewood infrastructure corridor. Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked (according to the Biobanking Assessment Methodology) as the additional patches formed would be separated by less than 100 m, the community in the study area is in moderate to good condition, the patch sizes would be mostly greater than 1 ha and the separation is not occurring by a dual carriageway or wider highway.

III. Whilst the habitat to be directly or indirectly impacted is in moderate to good condition, it is not considered important for the long-term survival of this community in the study region (the locality). The study area would still maintain over 99% of this community which could continue to allow this community to mature and regenerate in the study area. The non-impacted habitat is connected to additional patches of this community in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community is not likely to impact its long-term survival in the study region.

5. *Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).*

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this community in the study area.

6. *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

An action statement has been prepared for Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions. An action statement replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions and have been discussed in relation to the project:

1. *Encourage land managers to employ best management practice standards in controlling noxious weed or pest species in EECs.* The feral animal control strategy and the pest and weed management plan proposed to be implemented as part of the project would manage and monitor weed and pest species in this community.

2. *Develop a database of EEC sites on private land and determine site specific management strategies.* This community has been identified and mapped on private land in the study area. Biometric plots have also collected information of species composition, condition and habitat values present within this community. This data would be applicable to use as part of this management action.

3. *Collate mapping data and implement on ground mapping of this EEC to fill gaps.* This community has been identified and mapped in the study area. Biometric plots have also collected information of species composition, condition and habitat values present within this community. This data would be applicable to use as part of this management action.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to this community:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation

   - Loss of hollow-bearing trees
   - Removal of dead wood and dead trees.
- Environmental modification
   - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species composition is maintained. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The ecological scouting framework would also prioritise avoidance of this community where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions. The direct and indirect impact of less than 1% of the community in the study area is not considered significant and is unlikely to cause a local occurrence to become at risk of extinction in the long term.

Over 99% of the Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions ecological community in the study area would not be directly or indirectly impacted and it is unlikely that the extent or condition would be substantially changed.

The removal of 19.30 ha of the Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions ecological community in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches, nor are abotic factors necessary for the survival of the community likely to be modified or destroyed

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions.

Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions

Carbeen Open Forest occurs on the floodplains of the Meehi, Gwydir, Namoi, MacIntyre and Barwon rivers of north-western NSW. It is distributed from south of Moree to west of the Barwon River, extending east to just inside the Nandewar Bioregion. The community is found on flats and gentle rises of alluvial or aeolian sandy soils derived from ancient watercourses and can also occur at well-drained sandy sites on clay alluvial soils (DECCW 2010). This ecological community is known to occur within the study area near Yarrie Lake and along Bohena creek.

Carbeen Open Forest was originally an open forest community, which has now been reduced to woodland or remnant trees through extensive clearing and grazing. The characteristic tree species are *Corymbia tessellaris* (Carbeen) and *Callitris glaucophylla* (White Cypress Pine), with associated trees including *Corymbia dolichocarpa, Eucalyptus populnea, E. camaldulensis, Casuarina cristata* and *Allocasuarina luehmannii* (OEH 2016b). A small tree or shrub layer may be present, and there is an open forb and grass groundcover (DECCW 2010).

Within the study area, approximately 15.03 ha of this community has been mapped and approximately 133.26 ha of this community has been mapped in the study region. This community would be avoided and hence would not be directly or indirectly impacted.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

The project is unlikely to place the local occurrence of this ecological community at risk of extinction by having an adverse effect on the extent or by substantially and adversely modifying the composition.

I. This community would not be directly or indirectly impacted and hence the extent would not be reduced.

II. This community would not be modified and the composition would not be altered as no indirect impact would occur on this community.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. This community would not be directly or indirectly impacted.

II. No fragmentation or isolation of this community would occur.

III. No habitat of this community would be removed, modified, fragmented or isolated.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this community in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

An action statement has been prepared for Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions. An action statement replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions and have been discussed in relation to the project:

1. *Map extent and condition of EEC.* This community has been identified and mapped in the study area. Biometric plots have also collected information of species composition, condition and habitat values present within this community. This data would be applicable to use as part of this management action.

2. *Undertake weed control in accordance with guidelines.* The pest and weed management plan proposed to be implemented as part of the project would manage and monitor weed and pest species in this community.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

This community would not be directly or indirectly impacted and hence no key threatening processes would be likely to occur as a result of the project. There is potential for impact from habitat degradation by invasive fauna in the study area. However as this community would not be modified or fragmented as a result of the project, the key threatening processes associated with invasive species are not considered to be exasperated in this community by the project.

Conclusion

The project is considered unlikely to have a significant impact on Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions. This community would not be directly or indirectly impacted and hence it is unlikely a local occurrence would become at risk of extinction in the long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions.

Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions

Fuzzy Box Woodland is found on the alluvial soils of the South West Slopes, Brigalow Belt South and Darling Riverine Plains Bioregions, mainly in the Dubbo-Narromine-Parkes-Forbes area. It is found brown loam or clay, alluvial or colluvial soils, on prior streams, abandoned channels or slight depressions on undulating plains or flats (OEH 2016b). This community is known to occur within the study area.

The community is a tall woodland or open forest usually dominated by *Eucalyptus conica* (Fuzzy Box), which often grows with *E. microcarpa* (Inland Grey Box), *E. melliodora* (Yellow Box) or *Brachychiton populneus* (Kurrajong). *Allocasuarina luehmannii* (Buloke) may be common. In general, shrubs are sparse and the ground cover of forbs, low prostrate shrubs and grasses is moderately dense; however, this may vary with the season (OEH 2016b).

Within the study area, approximately 588.40 ha of this community has been mapped and approximately 2,674.66 ha of this community has been mapped in the study region. An upper limit of 5.90 ha would be directly impacted which equates to 1.00% directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 1.23 ha which would combine to impact a total of 1.21% in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

The project is unlikely to place the local occurrence of this ecological community at risk of extinction by having an adverse effect on the extent or by substantially and adversely modifying the composition.

I. The extent of this community predominantly follows Bohena Creek and its tributaries. Over 98% of this community would not be removed or indirectly impacted. The geographical extent would not be contracted or significantly intersected. Using the ecological scouting framework, areas of this community would be avoided where possible which would minimise the extent directly and indirectly impacted.

II. The composition of this community may be modified in areas that are indirectly impacted. The indirect impact would be comparable to removing 0.21% of this community in the study area. Over 98% of this community will not be directly or indirectly impacted and hence would not be adversely modified in composition. Vegetation clearing would be documented to ensure that clearing limits are not surpassed.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 5.90 ha of this community, which constitutes approximately 1.00% of this community in the study area. The project has potential to modify additional areas of this community as a result of indirect impacts. The reduction in vegetation structure and quality would be comparable to the loss of a further 1.23 ha of this community. The direct and indirect impact on this community would constitute a total impact of approximately 1.21% of this community in the study area.

II. Additional fragmentation of this community would occur as a result of the project. It is likely that additional patches of this community would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. Along the Bibblewindi to Leewood infrastructure corridor, one patch of this community would be additionally widened (the current corridor clearing is up to 10 m wide). This patch would consist of two smaller patches on either side of the corridor, approximately 2.5 ha and 4.5 ha in size. They are connected to nearby patches of this community by other vegetation communities, with the closest patches being within 350 m.

Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked (according to the Biobanking Assessment Methodology) as the additional patches formed would be separated by less than 100 m, the community in the study area is in moderate to good condition, the patch sizes would largely be greater than 1 ha and the separation is not occurring by a dual carriageway or wider highway.

III. Whilst the habitat to be directly or indirectly impacted is moderate to good condition, it is not considered important for the long-term survival of this community in the study region (the locality). The study area would still maintain over 98% of this community which could continue to allow this community to mature and regenerate in the study area. The non-impacted habitat is connected to additional patches of this community in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this community in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

An action statement has been prepared for Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions. An action statement replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions and have been discussed in relation to the project:

1. *Encourage land managers to employ best management practice standards in controlling noxious weed or pest species in EECs.* The feral animal control strategy and the pest and weed management plan proposed to be implemented as part of the project would manage and monitor weed and pest species in this community.

2. *Develop a database of EEC sites on private land and determine site specific management strategies.* This community has been identified and mapped on private land in the study area. Biometric plots have also collected information of species composition, condition and habitat values present within this community. This data would be applicable to use as part of this management action.

3. *Survey and map extant of Fuzzy Box Woodland EEC.* This community has been identified and mapped in the study area. This data would be applicable to use as part of this management action.

4. *Collate mapping data and implement on ground mapping of this EEC to fill gaps.* This community has been identified and mapped in the study area. Biometric plots have also collected information of species composition, condition and habitat values present

within this community. This data would be applicable to use as part of this management action.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to this community:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species composition is maintained. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The ecological scouting framework would also prioritise avoidance of this community where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions. The direct and indirect impact of less than 2% of the community in the study area is not considered significant and is unlikely to cause a local occurrence to become at risk of extinction in the long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on

Fuzzy Box Woodland on alluvial soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions.

Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions

Myall Woodland is scattered across the eastern parts of alluvial plains of the Murray-Darling river system, within the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South western Slopes bioregions. This ecological community is known to occur in the study area on private land west of Yarrie Lake.

Myall Woodland occurs on red-brown earths and heavy textured grey and brown alluvial soils in areas with an annual rainfall of 375 to 500 mm (OEH 2016b). The structure of this ecological community varies from low woodland and low open woodland to low sparse woodland or open shrubland. The tree layer may reach a height of around 10 metres and invariably includes *Acacia pendula* (Weeping Myall or Boree) as one of the dominant or only tree species present. The understorey includes an open layer of chenopod shrubs and other woody plant species and an open to continuous grass and herb groundcover. The shrub and canopy layers may have been reduced by clearing or heavy grazing in some districts; derived grassland may still constitute this community (OEH 2016b).

Within the study area, approximately 36.00 ha of this community has been mapped and approximately 126.09 ha of this community has been mapped in the study region. An upper limit of 0.10 ha would be directly impacted which equates to 0.28% directly impacted in the study area. No additional indirect impacts will result from the project.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

The project is unlikely to place the local occurrence of this ecological community at risk of extinction by having an adverse effect on the extent or by substantially and adversely modifying the composition.

I. The extent of this community is confined to the north of the study area and over 99% of this community would not be removed. No indirect impacts on this community are expected. The geographical extent would not be contracted or significantly intersected. Using the ecological scouting framework, areas of this community would be avoided where possible which would minimise the extent directly impacted.

II. Over 99% of this community will not be directly or indirectly impacted and hence would not be adversely modified in composition. Vegetation clearing would be documented to ensure that clearing limits are not surpassed.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 0.10 ha of this community, which constitutes approximately 0.28% of this community in the study area.

II. Additional fragmentation of this community may occur as a result of the project. It is possible that additional patches of this community would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. This community would not be intersected by the 30 m Bibblewindi to Leewood infrastructure corridor. Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked (according to the Biobanking Assessment Methodology) as the additional patches formed would be separated by less than 100 m, the community in the study area is in moderate to good condition, the patch size would be largely greater than 1 ha and the separation is not occurring by a dual carriageway or wider highway.

III. Whilst the habitat to be directly or indirectly impacted is moderate to good condition, it is not considered important for the long-term survival of this community in the study region (the locality). The study area would still maintain over 99% of this community which will allow this community to mature and regenerate in the study area. Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this community in the study area.

6. *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

An action statement has been prepared for Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions. An action statement replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions and have been discussed in relation to the project:

1. *Review and delineate distribution of the community from existing vegetation maps.* This community has been identified and mapped in the study area. This data would be applicable to use as part of this management action.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to this community:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species composition is maintained. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The ecological scouting framework would also prioritise avoidance of this community where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions. The direct and indirect impact of less than 1% of the community in the study area is not considered significant and is unlikely to cause a local occurrence to become at risk of extinction in the long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions.

1.3 Flora

Bertya opponens (Coolabah Bertya) – Vulnerable

Bertya opponens is a slender multi- or single-stemmed shrub that grows to four metres. This species has a highly restricted geographic distribution in NSW, and is known only from a few scattered sites including Coolabah, south of Narrabri on the North West Slopes, Cobar and the North Coast (NSW Scientific Committee 2009a). This species is known to occur in the north-east Pilliga Forest in Jacks Creek State Forest (ELA 2012), part of which is located within the study area.

When last assessed in 1999 the population on 'Nurrungal' consisted of 500-600 adult plants, whilst the population on 'Windera Station' is now believed to be extinct (NPWS 2002a). The population within Jacks Creek State Forest and adjoining private land is the most significant population of *Bertya opponens* in NSW and critical to the long term persistence of the species in the state. If the estimated 5,000,000 plants occurring in Jacks Creek State Forest is accurate, approximately 20% of the main population occurs within the study area. The species is known from numerous locations in central Queensland.

The habitats in which *B. opponens* is found include stony mallee ridges and cypress pine forest on red soils. The species is associated with a shrub layer of *Philotheca ciliata, Phebalium squamulosum* (Scaly Phebalium) and *Acacia* spp. and a sparse grassy groundcover (ELA 2012).

The area of occupied habitat in the study area is approximately 456 ha. Within this occupied habitat, this species occurs at an average density of 1,618 individuals per hectare. Approximately 956,861 individuals have been estimated to occur in the study area, based on habitat mapping calculations and supplementary extrapolation for sub-populations that are assumed to be present but have not yet been observed. An upper limit of 10,309 individuals would be removed or indirectly impacted which constitutes 1.08% of the number of individuals in the study area. An upper limit of 6.37 ha of occupied habitat in the study area would be directly or indirectly impacted which constitutes 1.40% of the occupied habitat in the study area.

1.	***In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The project is unlikely to place a viable local population of *Bertya opponens* at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.40% of occupied habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2.	***In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 10,309 individuals and up to 6.37 ha of occupied habitat in the study area. This constitutes approximately 1.08% reduction in abundance and 1.40% removal or indirect impact of occupied habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Bertya opponens* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m.

III. The habitat in the study area is part of a contiguous area of habitat that supports the largest known population of *Bertya opponens* in NSW and is important for the long-term survival of the species in the study region (the locality).

Bertya opponens has been recorded in dense patches in the north-east of the study area. The study area would still maintain over 98% of occupied habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

An approved recovery plan has been prepared for *Bertya opponens* (NPWS 2002a). Recovery objectives and actions of the recovery plan applicable to the project are provided below with description on how they have been addressed:

1. *Survey potential habitat for further populations*. Field surveys for this ecological assessment included both transects through a known population to achieve a more accurate estimation of population size and distribution as well as additional targeted surveys in suitable habitat to identify further populations.

2. *Survey*. Field surveys for this ecological assessment included both transects through a known population to achieve a more accurate estimation of population size and distribution as well as additional targeted surveys in suitable habitat to identify further populations.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process*.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
    - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
    - Competition and habitat degradation by feral goats (*Capra hircus*)
    - Invasion of native plant communities by exotic perennial grasses
    - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
    - Clearing of native vegetation
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Bertya opponens*. The direct and indirect impact of less than 2% of occupied habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Bertya opponens*.

***Diuris tricolor* (Painted Diuris) – Vulnerable**

Diuris tricolor is sporadically distributed on the western slopes of NSW, extending from south of Narrandera to the far north of NSW (OEH 2016b). Based on current records (OEH 2016a) the Pilliga forest population is separated from the nearest population to the south by approximately 100 km, and inter-population gene flow is likely to be absent or very limited. The broader Pilliga forest population of *D. tricolor* (including the study area occurrences) is regarded as significant because of its geographic separation and small number of individuals recorded. Throughout the range of the species in NSW it is usually recorded as common and locally frequent in populations (OEH 2016a), however in the study area only solitary plants were observed at sites. *D. tricolor* also occurs in Queensland and has a very restricted occurrence in Victoria where it is listed as endangered.

The species grows amongst grass in sclerophyll forest, often occurring with *Callitris spp.* (Cypress Pine). It is found on both flats and small rises in sandy soils, and has also been recorded from a red earth soil in a Bimble Box community in western NSW (OEH 2016b). It is most commonly found in Narrow-leaved Ironbark – White Cypress Pine - Buloke tall open forest dominated by *Eucalyptus crebra* (Narrow-leaved Ironbark) with shrubby midstorey dominated by *Callitris glaucophylla* (White Cypress Pine) and *Allocasuarina luehmannii* (Bulloak). The associated groundcover is often sparse grasses and occasionally shrubby (ELA 2012).

The study area supports 70,036 ha of potential habitat for this species. Approximately 3,353 individuals have been estimated to occur in the study area based on habitat modelling calculations (lower 95% confidence interval 1,743 individuals, upper 95% confidence interval 6,444 individuals). An upper limit of 52 individuals (27 – 100 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.54% of habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Diuris tricolor* at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.54% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 52 individuals and up to 1,081.78 ha of potential habitat in the study area. This constitutes approximately 1.55% reduction in abundance and 1.54% removal or indirect impact of potential habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as dispersal by *Diuris tricolor* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides important habitat for *Diuris tricolor*, it is not considered important for the long-term survival of the species in the study region (the locality).

Diuris tricolor has been recorded sporadically in the study area. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Diuris tricolor* has been assigned a keep-watch species as it is predicted to be secure in NSW for 100 years without targeted management at particular sites. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn't contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species and applicable ones have been discussed in relation to the project below:

1. *Conduct surveys and assessments of less known sites to confirm presence of species and develop and implement conservation management agreements with landholders for high priority sites*. The study area did not have well defined population information and hence field surveys for this ecological assessment were used to confirm presence of species. Information obtained could be used to inform the preparation of conservation management agreements.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Diuris tricolor*. The direct and indirect impact of less than 2% of potential habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Diuris tricolor*.

Lepidium aschersonii (Spiny Peppercress) – Vulnerable

Prior to commencing survey work for this assessment there were 29 records (from approximately 9 subpopulations) for the species in the study area (OEH 2016a). All of these records were concentrated within and around Brigalow Nature Reserve and Brigalow State Conservation Area. Although conditions were not favourable for detection of the species during fieldwork in the north western part of the study area in 2013 and 2014, 208 individuals (from four sub-populations) were recorded by ELA botanists. 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. These additional records have added considerably to the knowledge of the species in the study area.

Lepidium 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 study area. 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 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 (OEH 2016b), 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).

The species grows as a component of the ground flora on grey loamy clays (OEH 2016b). It is found on ridges of gilgai clays dominated by *Acacia harpophylla* (Brigalow), with *Rytidosperma* and/or *Austrostipa* spp. in the understorey. Vegetation structure varies from open to dense Brigalow, with a sparse grassy understorey and occasional heavy litter.

An upper limit of three individuals would be removed or indirectly impacted which constitutes 1.55% of the number of individuals known in the study area. Should surveys increase the known abundance of these species during the project, then the number of impacted individuals can increase but must stay below 1.55% of the population in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Lepidium aschersonii* at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of the population in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of

extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 1.55% of the population in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Lepidium aschersonii* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides important habitat for *Lepidium aschersonii*, it is not considered important for the long-term survival of the species in the study region (the locality).

Lepidium aschersonii has been recorded in the north-western portion of the study area. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Lepidium aschersonii* has been assigned a keep-watch species as relatively large populations of this species occur within reserves. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn’t contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species and applicable ones have been discussed in relation to the project below:

1. *Control feral goats, feral pigs and rabbits (best practice: locally/regionally efficient and effective).* The feral animal control strategy proposed as part of the project would manage and monitor feral goats, feral pigs and rabbits.

2. *Discourage fertilizer and pesticide drift.* The chemical management procedure proposed to be implemented as part of the project would manage chemical use to minimise the chance of chemicals indirectly impacting individuals and habitat.

3. *Fence sites and erect signs where human intrusion is a threat (e.g. trampling, parking or dumping)*. In areas managed by Santos where human intrusion could be possible, fencing would be erected to prevent access.

4. *Conduct weed control and regeneration of the vegetative community.* A pest and weed management plan proposed to be implemented as part of the project would control weeds in the study area and assist in promoting regeneration.

5. *Determine vegetation associations across the species entire range.* Habitat associations have been recorded when this species has been found in the study area.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process*.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Lepidium aschersonii*. The direct and indirect impact of less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Lepidium aschersonii*.

Lepidium monoplocoides (Winged Peppercress) – Endangered

Lepidium monoplocoides was not known from the study area prior to commencing survey work, however it was recorded from nearby in the Pilliga National Park and adjoining Pilliga State Conservation Area soon after (ELA 2012; Bell et al. 2012). During the course of vegetation sampling 258 individuals (from three subpopulations) were recorded within the study area towards the northern boundary, south west of Narrabri. The species is difficult to detect and given the dry conditions at the time when suitable habitat was surveyed, it is possible that the species is more frequent in the north western section of the study area than current records indicate.

Lepidium monoplocoides occurs in north western Victoria and South Australia, southern Queensland, and is widely distributed in semi-arid plains regions of NSW. 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. Although the population within the study area may not be large, it should be regarded as significant until further data clarifies the extent and size of populations in the greater Pilliga region.

Lepidium monoplocoides is known to occur on seasonally moist to waterlogged sites, on heavy fertile soils (OEH 2016b). The species is usually associated with open woodland dominated by *A. luehmannii* and/or eucalypts with a tussock grassy understorey. In the Pilliga National Park, this species has been found in Narrow-leaved Ironbark – White Cypress Pine - Buloke tall open forest, and was found to be associated with gilgais (ELA 2012). In the study area, it was found near roadsides and in run-on areas in Mugga Ironbark - White Cypress Pine - gum tall woodland.

An upper limit of four individuals would be removed or indirectly impacted which constitutes 1.55% of the number of individuals known in the study area. Should surveys increase the known abundance of these species during the project, then the number of impacted individuals can increase but must stay below 1.55% of the population in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Lepidium monoplocoides* at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of the population in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological

community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 1.55% of the population in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Lepidium monoplocoides* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides important habitat for *Lepidium monoplocoides*, it is not considered important for the long-term survival of the species in the study region (the locality).

Lepidium monoplocoides has been recorded in the north-western portion of the study area. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Lepidium monoplocoides* has been assigned a site-managed species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

One site, the Pilliga National Park, has been assigned for management of *Lepidium monoplocoides*. Conservation at this site is considered important for the long-term conservation of the species. The study area is not within this site.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening

***process*.**

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - o Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - o Competition and habitat degradation by feral goats (*Capra hircus*)
  - o Invasion of native plant communities by exotic perennial grasses
  - o Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - o Clearing of native vegetation
- Environmental modification
  - o High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Lepidium monoplocoides*. The direct and indirect impact of less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Lepidium monoplocoides*.

Myriophyllum implicatum – Critically Endangered

Myriophyllum implicatum was considered possibly extinct in NSW until it was rediscovered in Pilliga National Park by NSW Herbarium botanists in 2008. Subsequent surveys of ephemeral wetlands in the Pilliga National Park and adjoining Pilliga State Conservation Area undertaken in spring-summer 2010-2011 (Bell et al. 2012) found the species at four sites. A further NSW herbarium record from this general area was made in 2012 (Council of Heads of Australasian Herbaria 2014). All of these records are to the west or south west of the study area. The first record for the study area was made opportunistically in January 2014 on private property approximately 18 km south west of Narrabri. The plants were dead and partially disintegrated at the time of survey due to the prevailing drought conditions. As identification of specimens was not possible in the field, population estimates were not made, though potential habitat for the species at the collection locality has been mapped. Appropriately timed targeted survey following adequate rainfall events would enable population estimates to be made.

The population of *Myriophyllum implicatum* in the study area, along with those in the Pilliga National Park and adjoining Pilliga State Conservation Area, and one from near Brewarrina located in 2010 are the only known extant populations in NSW. A historical record from the NSW north coast region has not been recollected in recent years. Within the general Pilliga region *Myriophyllum implicatum* has a highly specialised habitat, occurring in shallow basin wetlands (sensu (Bell et al. 2012)), though the original 2008 collection was noted as occurring in a tank gilgai wetland. More extensive areas of potentially suitable habitat occur to the west of the study area between Pilliga National Park and Pilliga (Bell et al. 2012), and further survey work within this area, particularly to the west of the area surveyed by Bell et al. (2012), would help to clarify the abundance of *Myriophyllum implicatum* in the general Pilliga region. Until there is greater clarity the record from within the study area should be treated as highly significant. The species is not threatened in Queensland, where it is known from scattered near-coastal and inland locations from the NSW border northward to Cape York and the Gulf of Carpentaria (Council of Heads of Australasian Herbaria 2014).

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Myriophyllum implicatum* at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

No individuals of this species in the study area would be directly removed or indirectly impacted as a result of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological

community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. Habitat for this species would not be directly or indirectly impacted.

II. No fragmentation or isolation of habitat for this species would occur.

III. No habitat for this species would be removed, modified, fragmented or isolated.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Myriophyllum implicatum* has been assigned a site-managed species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

Two sites, the Pilliga Nature Reserve and a translocation site, have been assigned for management of *Myriophyllum implicatum*. Conservation at these sites is considered important for the long-term conservation of the species. The study area is not within these sites.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

This species would not be directly or indirectly impacted and hence no key threatening processes would be likely to occur as a result of the project. There is potential for impact from habitat degradation by invasive fauna in the study area. However as this species and its habitat would not be modified or fragmented as a result of the project, the key threatening processes associated with invasive species are not considered to be exasperated for this species by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Myriophyllum implicatum*. No direct or indirect impact would occur on this species or its habitat in the study area and hence it is unlikely a viable population would become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Myriophyllum implicatum*.

Polygala linariifolia (Native Milkwort) – Endangered

According to data from the Atlas of NSW Wildlife supplied by OEH at the commencement of surveys, the nearest record to the study area was 122 km to the north east. However, recent review of the Australian Virtual Herbarium and BioNet has identified several pre-2010 records of *Polygala linariifolia* in the vicinity of the study area. Specifically, an unvouchered record of *Polygala linariifolia* had been made in the south west corner of the study area, several unvouchered records had been made to the west-south west of the study area and a specimen had been collected from approximately 15 km north east of Narrabri (Council of Heads of Australasian Herbaria 2014; OEH 2016a).

The species was initially opportunistically located in the study area by ELA botanists in late 2010. Random meanders and fixed transects were undertaken during the 2010/11 phase of fieldwork and further transects surveyed in potential habitat in 2012. During the fieldwork it became apparent that rainfall history has a major influence on the detection of the species, with much larger numbers being located following significant rainfall events. A total of 1,475 plants were recorded within the study area from scattered locations predominantly in the southern third of the study area. The modelled population estimate for the study area is 16,317 individuals (lower 95% confidence interval 8,187 individuals, upper 95% confidence interval 28,095 individuals). The species was also recorded at eight locations outside the study area, each consisting of one to many individuals.

The broader Pilliga forest population of *Polygala linariifolia*, (including the study area occurrences) is significant because it is at the southern limit of the geographic range of the species. The species extends northward as scattered populations in the north western slopes and north coast (mostly north of Grafton) divisions of NSW. There is also an isolated occurrence in far western NSW near Weebah Gate (OEH 2016b). The NSW populations link up with those in Queensland where it is widely distributed and not listed as threatened.

The study area supports 69,940 ha of potential habitat for this species. An upper limit of 252 individuals (127 – 435 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Polygala linariifolia* at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to

the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 252 individuals and up to 1,081.78 ha of potential habitat in the study area. This constitutes approximately 1.55% reduction in abundance and 1.55% removal or indirect impact of potential habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as dispersal by *Polygala linariifolia* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides habitat for *Polygala linariifolia*, it is not considered important for the long-term survival of the species in the study region (the locality).

Polygala linariifolia has been recorded throughout the study area. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community are not likely to affect its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Polygala linariifolia* has been assigned a keep-watch species as it is now known to be more widespread than at the time of listing. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn't contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species but none are applicable to the project.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
    - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*

  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Polygala linariifolia*. The direct and indirect impact of less than 2% of potential habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Polygala linariifolia*.

Pomaderris queenslandica (Scant Pomaderris) – Endangered

Pomaderris queenslandica had not been recorded from the study area at the commencement of surveys, however there were records from within approximately 20 km of the north east boundary of the study area (Council of Heads of Australasian Herbaria 2014; OEH 2016a). Opportunistic records of the species were made by ELA botanists in the north eastern section of study area in 2012. Subsequently in 2014 a targeted survey of *P. queenslandica* was undertaken within the study area to determine the spatial characteristics of the population and to estimate the overall population size. Through this survey work it became apparent that the species is restricted to north eastern section of study area where it occurs in three separate areas. Within these areas the species occurs predominantly as small scattered subpopulations.

From the targeted surveys a total estimated population size of 45,518 individuals for the study area was calculated.

Most NSW populations of *Pomaderris queenslandica* occur towards the Queensland border, north and northwest of Armidale, in near-coastal areas between Newcastle and Coffs Harbour, north and south of Dubbo, and between Muswellbrook and Gulgong (OEH 2016a). The populations in the study area and others occurring approximately 20 km to the northeast towards Mt Kaputar and near Boggabri form a loose cluster separated from the nearest population by a significant distance of over 100 km. Until further information on the size of populations near Mt Kaputar and Boggabri is available, the population within the study area should be regarded as significant due to its considerable size and habitat quality. The species also occurs in Queensland, however it is not listed as threatened in that state.

The area of occupied habitat in the study area is approximately 90 ha. Within this occupied habitat, this species occurs at an average density of 324 individuals per hectare. Approximately 45,518 individuals have been estimated to occur in the study area, based on habitat mapping calculations and supplementary extrapolation for sub-populations that are assumed to be present but have not yet been observed. An upper limit of 467 individuals would be removed or indirectly impacted which constitutes 1.03% of the number of individuals in the study area. An upper limit of 1.44 ha of occupied habitat in the study area would be directly or indirectly impacted which constitutes 1.60% of the occupied habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Pomaderris queenslandica* at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.60% of occupied habitat in the study area. Reproduction, growth, development and aging would still be able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the

endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 467 individuals and up to 1.44 ha of occupied habitat in the study area. This constitutes approximately 1.03% reduction in abundance and 1.60% removal or indirect impact of occupied habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Pomaderris queenslandica* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m.

III. The habitat for *Pomaderris queenslandica* in the study area is part of a contiguous area of habitat and is important due to the considerable size and habitat quality of the population.

Pomaderris queenslandica has been recorded in patches in the north-east and east of the study area. The study area would still maintain over 98% of occupied habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat

(either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Pomaderris queenslandica* has been assigned a keep-watch species as it is predicted to be secure in NSW for 100 years without targeted management at particular sites. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn't contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species and applicable ones have been discussed in relation to the project below:

1. *Survey known locations and nearby areas for additional populations*. Field surveys for this ecological assessment included both transects through known occupied habitat to achieve a more accurate estimation of population size and distribution as well as additional targeted surveys in suitable habitat to identify further populations.

2. *Manage weeds at known populations.* A pest and weed management plan proposed to be implemented as part of the project would control weeds in the study area.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
    - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
    - Competition and habitat degradation by feral goats (*Capra hircus*)
    - Invasion of native plant communities by exotic perennial grasses
    - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
    - Clearing of native vegetation
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Pomaderris queenslandica*. The direct and indirect impact of less than 2% of occupied habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Pomaderris queenslandica*.

Pterostylis cobarensis (Greenhood Orchid) – Vulnerable

A solitary record of *Pterostylis cobarensis* was known from just north of the study area when survey work commenced. Although the collection was made by a reliable source it was treated with some uncertainty as it was an old record, over 200 km from the nearest record of the species and outside of the known distribution of the species as understood at that time. The species was initially opportunistically located in the study area by ELA botanists in spring 2011. Random meanders and fixed transects were undertaken during the 2011 phase of fieldwork and further transects surveyed in potential habitat during the peak flowering period in 2012. During that period of intensive fieldwork 240 individuals were recorded within the study area. Almost all records were made in the southern third of the study area, with few isolated records near the north western edge of the forested section of the study area. The modelled population estimate for the study area is 431,718 individuals (lower 95% confidence interval 338,850 individuals, upper 95% confidence interval 549,833 individuals). The species was also recorded on 170 occasions to the west and south of the study area boundary, each record consisting of one to many individuals.

The relationship of *P. cobarensis* to some related species and anomalous populations is still unresolved and opinions differ on the morphological limits of the species. OEH (2014a, 2014c) consider the species to be restricted to three main areas of distribution in NSW – north east of Broken Hill, within approximately 100 km of Cobar, and in the Pilliga forest. However, Council of Heads of Australasian Herbaria (2014) include additional collections (many of which have been determined by orchid taxonomist David Jones) under *P. cobarensis*, such as those scattered between Mildura and Sydney and south of Wagga Wagga. Beyond NSW the species extends westward into semi-arid South Australia and northward into southern Queensland. Although initially listed as threatened under the EPBC Act, the species was delisted in 2013 on the basis of its geographic distribution not being limited and no evidence of decline (TSSC 2010). Further taxonomic resolution is required before there can be clarity about the distribution and conservation status of the species. The population occurring in the Pilliga region (including the study area) is of significance because of its size and the quality of the habitat in which it occurs.

The study area supports 69,940 ha of potential habitat for this species. Approximately 431,718 individuals have been estimated to occur in the study area, based on habitat modelling calculations. An upper limit of 6,658 individuals (5,220 – 8,477 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.54% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Pterostylis cobarensis* at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological

community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 6,658 individuals and up to 1,081.78 ha of potential habitat in the study area. This constitutes an approximately 1.54% reduction in abundance and 1.55% removal or indirect impact of potential habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Pterostylis cobarensis* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides habitat for *Pterostylis cobarensis*, it is not considered important for the long-term survival of the species in the study region (the locality).

Pterostylis cobarensis has been recorded throughout the study area. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this community is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Pterostylis cobarensis* has been assigned a site-managed species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

Two sites, the Mundoorie travelling stock reserve and Yathong Nature Reserve, have been assigned for management of *Pterostylis cobarensis*. Conservation at these sites is considered important for the long-term conservation of the species. The study area is not within these sites.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Pterostylis cobarensis*. The direct and indirect impact of less than 2% of potential habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Pterostylis cobarensis*.

***Rulingia procumbens* – Vulnerable**

Rulingia procumbens was not known from the study area prior to commencing survey work, however it had been recorded just south in Pilliga Nature Reserve (OEH 2016a). Several other pre-2010 records had been made to the south and west within 50 km of the study area boundary. The species was initially opportunistically located in the study area in early 2011 and population counts and random meanders in suitable habitat were made at that time. Targeted transect surveys were undertaken in spring 2012 and additional population counts made opportunistically in late 2013 and early 2014. All records are from the far south eastern corner of study area, where they were found predominantly along the edge of tracks and recently burnt areas. A total of 359 individuals were recorded within the study area and the total population estimate for the north-east Pilliga (incorporating the study area) is 792,668 individuals. ELA botanists also recorded *R. procumbens* at 37 sites (comprising seven sub-populations) to the south of the study area boundary.

Rulingia procumbens is endemic to NSW. Beyond the Pilliga area populations are known from north east of Narrabri, the Dubbo–Medooran–Gilgandra region, south of Cobar, and the upper Hunter Valley (OEH 2016a; TSSC 2008). The broader Pilliga region population of *R. procumbens* (including the study area occurrences) is regarded as significant on the basis of its considerable size, habitat quality and lack of population size data for other known sites in NSW.

The study area supports 69,940 ha of potential habitat for this species. Approximately 240,274 individuals have been estimated to occur in the study area, based on habitat modelling calculations (lower 95% confidence interval 90,799 individuals, upper 95% confidence interval 858,601 individuals). An upper limit of 3,716 individuals (1,404 – 13,265 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Rulingia procumbens* at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 3,716 individuals and up to 1,081.78 ha of potential habitat in the study area. This constitutes approximately 1.55% reduction in abundance and 1.55% removal or indirect impact of potential habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Rulingia procumbens* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. Additionally, *Rulingia procumbens* was observed to occur frequently on previously cleared habitat, especially along unsealed roads in the study area.

III. Whilst the habitat to be directly or indirectly impacted provides habitat for *Rulingia procumbens*, it is not considered important for the long-term survival of the species in the study region (the locality).

Rulingia procumbens has been recorded throughout the study area, often on unsealed roads. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, *Rulingia procumbens* has been assigned a keep-watch species as it is predicted to be secure in NSW for 100 years without targeted management at particular sites. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn’t contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species and applicable ones have been discussed in relation to the project below:

1. *Conduct baseline surveys to locate new populations and extend the ranges of known populations.* Field surveys for this ecological assessment included both counts of individuals at known occupied habitat to achieve a more accurate estimation of population size and distribution as well as additional targeted surveys in suitable habitat to identify further populations.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - o Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - o Competition and habitat degradation by feral goats (*Capra hircus*)
  - o Invasion of native plant communities by exotic perennial grasses

  - o Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - o Clearing of native vegetation
- Environmental modification
  - o High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Rulingia procumbens*. The direct and indirect impact of less than 2% of potential habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Rulingia procumbens*.

Tylophora linearis – Vulnerable

Tylophora linearis had not been recorded from the study area prior to commencing survey work, however it had been recorded at three sites within approximately 50 km south and south west of the study area (OEH 2016a). The species was initially opportunistically located in the study area in 2011. Targeted transect surveys for the species were undertaken in 2011 and 2012, and additional records were made as part of other studies between 2012 and 2014. A total of 376 individuals were recorded, all within the southern half study area. On the basis of population data presented by the NSW Scientific Committee (NSW Scientific Committee 2008c), this would be the largest population known in NSW. ELA botanists also recorded *T. linearis* at 30 sites (mostly comprising individual plants) to the west and south of the study area boundary. During survey work, plants were commonly observed to be clonal, with numerous stems arising within a radius of up to 5 m. These clonal masses were assumed to be individual plants, rather than each stem representing an individual plant, a view supported by NSW Scientific Committee

(NSW Scientific Committee 2008c). A greater understanding of the ecology of the species was gained through work in the Pilliga region, which revealed that although *T. linearis* occurs in a broad range of vegetation types in the area; it was most often found in areas heavily burnt by the 2007 wildfire, along track edges and in recently cut road drains.

In NSW *Tylophora linearis* is known from relatively few scattered populations in the western slopes division, from Temora in the south to near Yetman in the north (OEH 2016a). The cryptic nature of the species, and its preference for growing in areas of little agricultural value, suggest that it may be still present in numerous areas which are currently considered gaps for the species (NSW Scientific Committee 2008c). The broader Pilliga region population of *T. linearis* (including the study area occurrences) is regarded as significant on the basis of its estimated large size and habitat quality. The species also occurs in the Glenmorgan district in southern Queensland, where it is very rare and poorly known.

The study area supports 69,940 ha of potential habitat for this species. Approximately 33,154 individuals have been estimated to occur in the study area, based on habitat modelling calculations (lower 95% confidence interval 25,739 individuals, upper 95% confidence interval 43,717 individuals). An upper limit of 513 individuals (398 – 676 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of *Tylophora linearis* at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality. In order to place the population at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for flowering, dispersal, pollination, fruiting and seed production. Growth requires adequate habitat and conditions for germination and healthy vegetative growth. Development requires adequate habitat and conditions for vegetative growth and flowering. Aging requires adequate habitat and conditions to maintain healthy vegetative growth and continue flowering. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting over 1.55% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the

endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 513 individuals and up to 1,081.78 ha of potential habitat in the study area. This constitutes approximately 1.55% reduction in abundance and 1.55% removal or indirect impact of potential habitat in the study area.

II. Additional fragmentation of habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as dispersal by *Tylophora linearis* during the reproduction phase would still be possible between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

III. Whilst the habitat to be directly or indirectly impacted provides important habitat for *Tylophora linearis*, it is not considered necessary for the long-term survival of the species in the study region (the locality).

Tylophora linearis has been recorded throughout the study area, with a patch of high density occurring along the southern edge of X-line Road. The study area would still maintain over 98% of potential habitat in the study area. The non-impacted habitat is connected to additional habitat in the study region (the locality). Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on this species is not likely to impact its long-term survival in the study region.

5.	***Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).***

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for this species in the study area.

6.	***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

Under the Saving our Species program, *Tylophora linearis* has been assigned a keep-watch species as it is predicted to be secure in NSW for 100 years without targeted management at particular sites. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The species action statement doesn't contain specific management actions for this species as it is not considered required at this stage. State-wide conservation actions have been identified for this species and applicable ones have been discussed in relation to the project below:

1. *Protect all known sites immediately from any type of disturbance (fire, grazing, forestry operations, etc) until such time as its conservation status is fully known and recovery actions are better developed.* The study area contains known sites of occupancy for this species. All records within areas to be disturbed are provided to regulators and the project would only impact on approved numbers of individuals. The area of high density of *Tylophora linearis* adjacent to X-line Road has been ranked as moderate – high sensitivity (second highest category) in the ecological sensitivity analysis to minimise impact.

2. *Determine the full extent, distribution and viability of surviving populations and identify at least 6 populations across the species range for implementation of recovery actions.* Targeted surveys for this ecological assessment identified individuals and assessed and modelled the extent and distribution of the population in the study area.

7.	***Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

The following key threatening processes are likely to occur and are relevant to this species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus)*
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification

- o High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of habitat degradation by feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and minimise habitat competition from weed species reducing the potential for significant impacts on this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The ecological scouting framework would also prioritise avoidance of this species where possible. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on *Tylophora linearis*. The direct and indirect impact of less than 2% of potential habitat and less than 2% of individuals in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on *Tylophora linearis*.

1.4 Birds

Parrots

Calyptorhynchus lathami (Glossy Black-cockatoo), *Glossopsitta pusilla* (Little Lorikeet) and *Neophema pulchella* (Turquoise Parrot) are considered in this impact assessment.

***Calyptorhynchus lathami* (Glossy Black-cockatoo) – Vulnerable**

The Glossy Black-cockatoo is uncommon although widespread throughout suitable habitats, from the central Queensland coast to East Gippsland in Victoria, and inland to the southern tablelands and central western plains of NSW, with a small population in the Riverina. An isolated population also exists on Kangaroo Island, South Australia (OEH 2016b). The species is known to occur within the study area and has been recorded at a wide range of locations.

The Glossy Black-Cockatoo is associated with a variety of open eucalypt forest and woodland types containing a midstorey of *Allocasuarina* spp. and *Casuarina* spp.. This vegetation is usually indicative of the poor nutrient status of underlying soils (Garnett & Crowley 2000; OEH 2016b). Intact drier forest types located in less-rugged landscapes are preferred (OEH 2016b). In the study area, the species is known to utilise a range of habitat types: water bodies, grassy woodland, heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. In the study area, this species was observed feeding on *Allocasuarina diminuta* subsp. *diminuta* and *Callitris* spp.

Within the study area, approximately 66,805 ha of habitat has been mapped which provides 66,005 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 292,431 ha of habitat has been mapped which provides 265,711 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 861.80 ha of habitat would be directly impacted (854.20 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.29%of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (169.18 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.55%of both foraging and breeding habitat in the study area.

Glossopsitta pusilla **(Little Lorikeet) – Vulnerable**

The Little Lorikeet is distributed widely across the coastal and Great Divide regions of eastern Australia, from Cape York to South Australia. A large component of the species' core habitat is located in NSW, and it is found from the coast westward as far as Dubbo and Albury. Nomadic movements are common, influenced by season and food availability, although some areas (such as the breeding population on the north-western slopes) retain residents for much of the year (OEH 2016b). The species is known to occur within the study area and has been recorded at a wide range of locations.

Little Lorikeets mostly occur in dry, open eucalypt forests and woodlands, including remnant woodland patches and roadside vegetation. They feed primarily on nectar and pollen in the tree canopy, particularly on profusely-flowering eucalypts, but also on a variety of other species including melaleucas and mistletoes (Courtney & Debus 2006; Higgins 1999). On the western slopes and tablelands, *Eucalyptus albens* and *E. melliodora* are important food sources for pollen and nectar respectively. Riparian habitats are favoured due to higher soil fertility and thus greater productivity (OEH 2016b). In the study area, the Little Lorikeet has been recorded in grassy woodland, riparian woodland and shrub-grass woodland habitats, and is predicted to also utilise waterbodies, heathy woodland and shrubby woodland.

Within the study area, approximately 66,805 ha of habitat has been mapped which provides 66,805 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 292,431 ha of habitat has been mapped which provides 292,431 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 861.80 ha of habitat would be directly impacted (861.80 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.29% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.55% of both foraging and breeding habitat in the study area.

Neophema pulchella **(Turquoise Parrot) – Vulnerable**

The Turquoise Parrot’s range extends from southern Queensland through to northern Victoria, from the coastal plains to the western slopes of the Great Dividing Range (OEH 2016b) The species is known to occur within the study area and has been recorded at a wide range of locations, primarily along riparian corridors.

The Turquoise Parrot mainly inhabits eucalypt and cypress pine open forests and woodlands — commonly box or box-ironbark — with native grasses, and sometimes a low shrubby understorey (NSW Scientific Committee 2009b). It also lives in open woodland or riparian gum woodland, and often near ecotones between woodland and grassland, or coastal forest and heath. It frequently occurs in undulating or rugged country, including steep rocky ridges, gullies, rolling hills and valleys (Marchant & Higgins 1993). Richer habitats such as river flats and footslopes are preferred, but have been largely cleared for agriculture (NSW Scientific Committee 2009b). In the study area, it is known to utilise closed forest, grassy woodland, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. Predicted habitat also includes water bodies, grasslands and heath.

Within the study area, approximately 77,671 ha of habitat has been mapped which provides 77,671 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 340,751 ha of habitat has been mapped which provides 340,751 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 965.60 ha of habitat would be directly impacted (965.60 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.24% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 176.41 ha of habitat (176.41 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.47% and 1.55% of foraging habitat and breeding habitat respectively in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Glossy Black-cockatoo, Little Lorikeet or Turquoise Parrot at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the three assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, reducing the removal of hollow-bearing trees, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to

have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 861.80 ha of habitat for Glossy Black-cockatoo and Little Lorikeet, which provides 854.20 ha of foraging habitat for Glossy Black-cockatoo, 861.80 ha of foraging habitat for Little Lorikeet and 861.80 ha of breeding habitat for both species. This constitutes approximately 1.29% of foraging and breeding habitat removed in the study area for both species. Up to 965.60 ha of habitat for Turquoise Parrot would be removed (965.60 ha of foraging habitat and 861.80 ha of breeding habitat) which constitutes 1.24% of foraging habitat and 1.29% of breeding habitat.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 170.71 ha for Glossy Black-cockatoo and Little Lorikeet and 176.41 ha for Turquoise Parrot. This provides 169.18 ha of foraging habitat and 170.71 ha of breeding habitat for Glossy Black-cockatoo and 170.71 ha of foraging and breeding habitat for Little Lorikeet. For Turquoise Parrot, this habitat provides 176.41 ha of foraging habitat and 170.71 ha of breeding habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.55% of foraging and breeding habitat in the study area for Glossy Black-cockatoo and Little Lorikeet. For Turquoise Parrot, it would constitute a total impact of 1.47% of foraging habitat and 1.55% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the three assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the three assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the three assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the three assessed species in the study region (the locality).

The study area provides important foraging and breeding habitat for the three assessed species and they are known to occupy this habitat in the study area. This habitat directly links to important habitat and areas of known occupancy in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the three assessed species in the study region.

Hollow-bearing trees are an important habitat feature for the three assessed species. Using the ecological scouting framework to avoid removing hollow-bearing trees where possible during design is an important measure for maintaining important habitat in the study area.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Glossy Black-cockatoo has been assigned a site-managed species and Little Lorikeet and Turquoise Parrot have been assigned landscape species. A species action statement has been prepared for each of these species and replaces the requirement to prepare a recovery plan (DECC 2007).

Two management sites have been established for Glossy Black-cockatoo where conservation activities need to take place to ensure the conservation of this species; Central West and North Coast. The study area is located within the Central West site which extends across 15 local government areas; Cabonne, Coonamble, Dubbo, Forbes, Gilgandra, Gunnedah, Mid-Western Regional, Narrabri, Narromine, Parkes, Upper Hunter, Walgett, Warrumbungle and Wellington. The following management actions are applicable for Glossy Black-Cockatoo and have been discussed in relation to the project:

1. *Nest-hollow loss: increase number and density of potential nest-sites*. Hollow-bearing tree removal is being minimised through implementation of the ecological scouting framework. Habitat in the study area not directly impacted (over 98% of breeding and

foraging habitat) would form additional hollows over the duration of the project and would not be subjected to removal for other purposes (i.e. forestry).

2. *Track species abundance / condition over time*. The biodiversity monitoring proposed to be undertaken as part of the project would record abundance over time.

The following management actions are applicable for Little Lorikeet and have been discussed in relation to the project:

1. *Encourage retention of old-growth and hollow-bearing trees through community engagement and other mechanisms including PVPs, BioBanking and EIA*. Hollow-bearing tree removal is being minimised through implementation of the ecological scouting framework.

2. *Avoid burning woodland with old-growth and hollow-bearing trees*. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

The following management actions are applicable for Turquoise Parrot and have been discussed in relation to the project:

1. *Select targeted areas where large populations occur and liaise with landholders to protect hollow-bearing trees*. Hollow-bearing tree removal is being minimised through implementation of the ecological scouting framework.

2. *Control feral cats and foxes near high density populations (best practise*: *locally efficient and effective)*. The feral animal control strategy proposed as part of the project would manage and monitor feral cats and foxes.

3. *Control feral goat and pigs of known or potential habitat*. The feral animal control strategy proposed as part of the project would manage and monitor feral goats and pigs.

4. *Control weeds at priority sites*. A pest and weed management plan proposed to be implemented as part of the project would minimise weed transportation and manage weeds in the study area.

Predation by foxes is listed as a threat for Turquoise Parrot (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the three assessed species:

- Invasive species
    - Competition and habitat degradation by feral goats (*Capra hircus*) (Turquoise Parrot only)
    - Competition from feral honey bees (Apis mellifera)
    - Predation by the European Red Fox (Vulpes vulpes) (Turquoise Parrot only)
    - Predation by the feral cat (*Felis catus*) (Turquoise Parrot only)
    - Predation, habitat degradation, competition and disease transmission by feral pigs (Sus scrofa) (Turquoise Parrot only).
- Direct impact
    - Clearing of native vegetation
    - Loss of hollow-bearing trees
    - Removal of dead wood and dead trees.
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Glossy Black-cockatoo, Little Lorikeet or Turquoise Parrot. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Glossy Black-cockatoo, Little Lorikeet or Turquoise Parrot.

Parrots – winter migratory

Lathamus discolor (Swift Parrot) and *Polytelis swainsonii* (Superb Parrot) are considered in this assessment.

Lathamus discolor (Swift Parrot) – Endangered

The Swift Parrot is endemic to south-eastern Australia. It breeds in Tasmania during spring and summer, migrating in the autumn and winter months to the box-ironbark forests and woodlands of south-eastern mainland Australia, from Victoria and the eastern parts of South Australia to south-east Queensland. In NSW, the species mostly occurs on the coast and south west slopes (OEH 2014b).

There are no records of Swift Parrot in the Pilliga (OEH 2016a); however, it has the potential to use habitat in the Pilliga occasionally for foraging during the winter, and has been recorded in the Namoi catchment area (OEH 2016b). Whilst overwintering on the mainland, Swift Parrots are semi-nomadic, foraging in areas where eucalypts are flowering profusely or where there are abundant psyllid infestations as they feed extensively on nectar and lerps during the non-breeding season (DotE 2016b).

Swift Parrots are known to prefer *Eucalyptus sideroxylon* (Mugga Ironbark) and box-ironbark woodland for foraging, actively selecting medium to large trees. Sightings are often correlated with drainage lines (DotE 2016b). Although they exhibit high site fidelity, droughts and low food abundance in preferred sites will cause them to use other areas of critical food resource (box-ironbark habitat in drainage lines is thought to act as a critical food resource during these times (DotE 2016b)). Predicted habitat for the species within the study region includes water bodies, grassy woodland, heath, heathy woodland, riparian woodland and shrub-grass woodland.

Within the study area, approximately 57,579 ha of habitat has been mapped which provides 57,579 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 246,370 ha of habitat has been mapped which provides 246,370 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 796.80 ha of foraging habitat would be directly impacted which equates to 1.38% of foraging habitat in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 157.48 ha of foraging habitat, which would combine to impact a total of 1.66% of foraging habitat in the study area.

***Polytelis swainsonii* (Superb Parrot) – Vulnerable**

The Superb Parrot is found in NSW and northern Victoria, where it occurs on the inland slopes of the Great Divide and on adjacent plains, especially along the major river-systems. On occasion, vagrants have been recorded in southern Queensland. The core breeding area is located on the South-western Slopes of NSW. Birds breeding in this region are mainly absent during winter, when they migrate north to the region of the upper Namoi and Gwydir Rivers. There are scattered records of Superb Parrot in the Pilliga, mainly fringing the vegetated areas in the north, south and west (OEH 2016a). The other main breeding sites are in the Riverina along the corridors of the Murray, Edward and Murrumbidgee Rivers where birds are present all year round (OEH 2016b). The species is not known to breed in the Pilliga. There is the potential for this species to occur in the study area during the non-breeding season (winter).

The Superb Parrot inhabits box-gum woodland, Box-Cypress-pine and Boree Woodlands and River Red Gum Forest. The populations that migrate to the Namoi region in winter forage and roost in forests and woodlands dominated by *Callitris glaucophylla* (White Cypress Pine) and Box-gum. Previous sightings of Superb Parrot in the Pilliga Forest have been associated with drainage lines, foraging in Eucalypt canopy and grassland and flying through the landscape (OEH 2016a). The Superb Parrot forages on the ground, in understorey shrubs and in the forest canopy, feeding on the seeds of native and exotic grasses, cereal crops, spilt grain, acacias seeds, eucalypt flowers and fruits, mistletoe berries and lerps (Christie 2004; Frith & Calaby 1953; Webster 1988; Webster & Ahern 1992). Water bodies, riparian woodland and shrub-grass woodland are the habitat types predicted to be potential habitat for the species within the study area.

No Superb Parrots have been recorded in the study area.

Within the study area, approximately 35,574 ha of habitat has been mapped which provides 35,574 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 195,490 ha of habitat has been mapped which provides 195,490 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 416.80 ha of foraging habitat would be directly impacted which equates to 1.17% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 82.02 ha of foraging habitat, which would combine to impact a total of 1.40% of foraging habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Swift Parrot or Superb Parrot at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

The Swift Parrot and Superb Parrot do not have breeding habitat in the study area as their known breeding territories are not located within the study area. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

The study area is considered to provide an alternative foraging resource when more favourable foraging habitat is not available or during seasons when flowering in the study area is more profuse. This supplementary habitat has potential to support the developmental and ageing phases of their lifecycle. Death is not considered a stage of the lifecycle which needs to be assessed.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the two assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would continually inhibit development and aging. Development requires adequate habitat and conditions for foraging, roosting, communication and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting.

Impacts to the developmental and aging phases on the lifecycle for the two assessed species would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna, ensuring development would not increase collisions (either vehicular or by flying into buildings or fences) and not directly or indirectly impacting over 98% of habitat in the study area. Development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 796.80 ha of supplementary foraging habitat for Swift Parrot and 416.80 ha of supplementary foraging habitat for Superb Parrot. No breeding habitat for either species would be removed. This constitutes approximately 1.38% of Swift Parrot habitat and 1.17% of Superb Parrot habitat removed in the study area. The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 157.48 ha of Swift Parrot habitat and 82.02 ha of Superb Parrot habitat. The direct and indirect impact on the supplementary foraging habitat would constitute a total impact of approximately 1.66% of Swift Parrot habitat and 1.40% of Superb Parrot habitat.

II. Additional fragmentation of foraging habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the two assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the two assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the two assessed species would be possible around the infrastructure.

III. The study area does not support breeding for either species. Additionally, both species have a degree of site fidelity for foraging during their migration and a known important foraging site is not known in the study area. The study area does support habitat that could potentially be used as foraging habitat when foraging resources at favourable sites are not available or during seasons when flowering in the study area is more profuse. The magnitude and duration of the direct and indirect impacts on the supplementary foraging habitat is not likely to impact the long-term survival of the assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Swift Parrot and Superb Parrot have been assigned landscape species. A species action statement has been prepared for each of these species and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Swift Parrot and have been discussed in relation to the project:

1. *Identify and map the extent and quality of Swift Parrot foraging and roosting habitat on private and public land*. All potential foraging habitat has been identified and mapped in the study area.

2. *Reduce the incidence of Swift Parrot collisions (including windows/glass panes and high wire-mesh fences) in the vicinity of suitable habitat.* Fauna friendly fencing would be used in the study area.

The following management actions are applicable for Superb Parrot and have been discussed in relation to the project:

1. *Identify non-breeding movement corridors and foraging habitat*. All potential foraging habitat in the study area has been identified and mapped.

2. *Continue and expand the network of community observers and landholders that report locations of birds*. Records of the Superb Parrot would be supplied to OEH under the OEH licence agreement. Data recorded would include the location, habitat use and behaviour of the observed Superb Parrots.

Predation by foxes is listed as a threat for Superb Parrot as they feed on the ground (OEH 2016b). Hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation.

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species.

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes.

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the two assessed species:

- Invasive species
    - Predation by the European Red Fox (*Vulpes vulpes*) (Superb Parrot only)
    - Predation by the feral cat (*Felis catus*)
- Direct impact
    - Clearing of native vegetation
    - Loss of hollow-bearing trees
    - Removal of dead wood and dead trees.
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Superb Parrot or Swift Parrot. The direct and indirect impact of less than 2% of supplementary foraging habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Superb Parrot or Swift Parrot.

Owls

Ninox connivens (Barking Owl) and *Tyto novaehollandiae* (Masked Owl) are considered in this assessment.

Ninox connivens* (Barking Owl) – *Vulnerable

The Barking Owl is found throughout most of mainland Australia apart from the central arid regions. Although common in parts of northern Australia, the species has declined greatly in southern Australia and now occurs in a wide but sparse distribution in NSW (OEH 2016b). Core populations exist on the western slopes and plains and in some northeast coastal and escarpment forests (OEH 2016b). The Pilliga Forest, particularly the western Pilliga, is a stronghold of the Barking Owl, and supports the largest remaining population of the species in NSW (NPWS 2003; Kavanagh & Stanton 2009). Barking Owls were detected at several locations in the north-west of the study area, near Yarrie Lake, and along Bundock Creek and Mollee Creek. Barking Owls were previously known at Yarrie Lake and along Bundock Creek (OEH 2016a). Two known Barking Owl territories in the Pilliga Forest overlap with the study area; one along Bohena Creek and the other near Oakyhole Creek (Milledge 2004).

The Barking Owl is associated with a variety of habitats such as savannah woodland, open eucalypt forest, wetland and Riverine forest. It is flexible in its habitat use, and hunting can extend in to closed forest as well as more open cleared areas. Habitat is typically dominated by Eucalypts (often Redgum species). It roosts in dense shaded foliage in large trees such as Casuarinas and Allocasuarinas, Eucalypts, Angophoras, Acacias and other large trees (OEH 2016b). Nesting occurs in hollows in large, old eucalypts, either living or dead. In the eastern Pilliga, the Barking Owl is known to utilise closed forest, heathy woodland, riparian woodland and shrub-grass woodland; all other habitat types known in the study area constitute predicted habitat for the species.

In most habitats, sparse prey densities mean that very large permanent territories are required, and pairs may hunt over 2000-6000 hectares. This would roughly indicate that records over 5 km to 8 km apart are possibly different individuals. In the study area, three Barking Owls were observed at Yarrie Lake, and two Barking Owls were observed both along Mollee Creek and Bundock Creek. These records are between 8 km to 10 km apart.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 69,531 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.45% and 1.53% of foraging habitat and breeding habitat respectively in the study area.

Tyto novaehollandiae* (Masked Owl) – *Vulnerable

The Masked Owl is found in a broad coastal band around most of mainland Australia and throughout Tasmania. In NSW, its range extends from the coast (where it is most abundant) to the western plains, occurring in most of the state aside from the most arid north-western corner. There is no seasonal variation in its distribution (OEH 2016b). In the study area, Masked Owl responded to call playback in two separate locations, east of Bohena Creek. A previous record of Masked Owl was also from east of Bohena Creek (Kendall and Kendall Ecological Consultants 2006).

The species is associated with forest with sparse, open, understorey, typically dry sclerophyll forest and woodland (OEH 2016b) and especially the ecotone between wet and dry forest, and non-forest habitat (Garnett & Crowley 2000). The species is known to utilise forest margins, isolated stands of trees within agricultural land and heavily disturbed forest for hunting, where its preferred prey of small and medium sized mammals can be readily obtained (Kavanagh & Peake 1993). The Masked Owl roosts and breeds in moist eucalypt-dominated forested gullies. Nesting occurs in large tree hollows or, occasionally, in caves. Pairs have a large home-range of 500 to 1000 hectares. The species has been recorded using shrub-grass woodland habitat and it is predicted to occur in all other habitat types in the study area. As all records were from call playback, it is not possible to know the exact location of Masked Owl and hence the number of home ranges has not been predicted.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 69,531 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.45% and 1.53% of foraging habitat and breeding habitat respectively in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Barking Owl or Masked Owl at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the three assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoidance of known nest trees, avoidance of buffered vegetation surrounding known nest trees, staged construction, progressive rehabilitation, reducing the removal of hollow-bearing trees (also suitable for prey species), controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 988.80 ha of habitat for Barking Owl and Masked Owl, which provides 988.80 ha of foraging habitat and 885.00 ha of breeding habitat for both species. This constitutes approximately 1.23% of foraging habitat and 1.27% of breeding habitat removed in the study area for both species.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 181.11 ha of habitat for Barking Owl and Masked Owl which provides 181.11 ha of foraging habitat and 175.41 ha of breeding habitat for both species. The direct and indirect impact on habitat would constitute a total impact of approximately 1.45% of foraging habitat and 1.53% breeding habitat in the study area for both species.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the two assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the two assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the two assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the two assessed species in the study region (the locality).

The study area supports known territories for at least three breeding pairs of Barking Owl. There are also scattered records of Masked Owl in the study area, indicating that with additional research, it would be possible to find Masked Owl breeding territories also occurring in the study area.

The study area provides important foraging and breeding habitat for the two assessed species. This habitat directly links to important habitat and areas of known occupancy in the study region (the locality). Mitigation measures recommending avoidance of known nest trees would insure that important habitat features are not impacted. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the three assessed species in the study region.

Large hollow-bearing trees are an important habitat feature for the assessed species. Using the ecological scouting framework to avoid removing hollow-bearing trees where possible during design is an important measure for maintaining important habitat in the study area. The ecological scouting framework would ensure data on hollow size was recorded to ensure large hollows suitable for nest sites are identified and avoided where possible. Signs of large owl nest sites recorded during the pre-clearance survey would instigate further surveys to identify additional nest sites in the study area.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a

recovery plan or threat abatement plan.

The Masked Owl is addressed in the recovery plan for the large forest owls (DEC 2006a). The Barking Owl has a draft NSW recovery plan (NPWS 2003).

Recovery objectives of the recovery plan for the large forest owls applicable to the project are provided below with description on how they have been addressed:

1. *Model and map owl habitat and validate with surveys*. Masked Owl habitat has been mapped in the study area. Spotlighting and call playback surveys have been undertaken throughout the study area. Locations of individuals have been recorded.

2. *Monitor owl population parameters*. Additional records of Masked Owl in the study area would be recorded. This would include numbers of individuals, location, behaviour and signs of breeding.

3. *Manage and protect habitat off reserves and state forests*. The potential impacts on Masked Owl and its habitat in the study area has been addressed in this Ecological Impact Assessment. In particular, habitat clearing including the removal of hollow-bearing trees has been minimised as possible.

4. *Increase community awareness and involvement in owl conservation*. Records of Masked Owl would be supplied to OEH under the OEH licence agreement and would be available for public use.

Recovery objectives of the Barking Owl draft NSW recovery plan are provided below with description on how they have been addressed:

1. *Increase understanding of the biology, ecology and management of the Barking Owl*. Records of Barking Owl would be supplied to OEH under the OEH licence agreement and would be available for public use. Data recorded would include the number of individuals, location, habitat use and behaviour of the observed Barking Owl. Threat management would be monitored and reported on for increased understanding.

2. *Undertake threat abatement and mitigation.* Known Barking Owl territories in the study area have been digitised from Milledge (2004) and locations of known nest trees would be sought from OEH to ensure avoidance as part of the ecological scouting framework. Fauna friendly fencing, management of vehicular speed and activity from dusk through to dawn, feral animal control and appropriate buffers for minimising disturbance would also be applied.

3. *Gain efficiencies through links with other conservation plans and conservation groups.* Consultation with OEH and other relevant conservation groups would ensure the monitoring and management of Barking Owl would be up to date with current knowledge.

Predation by foxes is listed as a threat for the large forest owls (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to these species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to the two assessed species:

- Invasive species
  - Competition from feral honey bees (*Apis mellifera*)
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Barking Owl or Masked Owl. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Barking Owl or Masked Owl.

Birds of prey

Circus assimilis (Spotted Harrier), *Falco hypoleucos* (Grey Falcon), *Falco subniger* (Black Falcon), *Hamirostra melanosternon* (Black-breasted Buzzard), *Hieraaetus morphnoides* (Little Eagle), and *Lophoictinia isura* (Square-tailed Kite) are considered in this assessment.

Circus assimilis* (Spotted Harrier) – *Vulnerable

The Spotted Harrier occurs throughout the Australian mainland, excepting the densely forested habitats of the coast, escarpment and ranges (Barrett, et al., 2003). It occurs only rarely in Tasmania. Individuals disperse widely in NSW and comprise a single population (OEH 2016b). In the study area, the species has been observed flying over cleared habitat, east of Bohena Creek. It has previously been recorded within 5 km from this location, but the record was from over 30 years ago (OEH 2016a).

Spotted Harrier occurs in grassy open woodland, including Acacia and mallee remnants, inland riparian woodland, grassland and shrub steppe (Marchant & Higgins 1993). It is found most commonly in native grassland, but also occurs in agricultural land, foraging over open habitats including edges of inland wetlands (OEH 2016b). In the study area, the Spotted Harrier is predicted to use water bodies, grassland, grassy woodland, riparian woodland and shrub-grass woodland habitats.

Within the study area, approximately 45,663 ha of habitat has been mapped which provides 45,663 ha of foraging habitat and 36,098 ha of breeding habitat. Within the study region, approximately 251,845 ha of habitat has been mapped which provides 251,845 ha of foraging habitat and 211,106 ha of breeding habitat. An upper limit of 498.70 ha of habitat would be directly impacted (498.70 ha of foraging habitat and 422.80 ha of breeding habitat) which equates to 1.09% of foraging and 1.17% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat) which would combine to impact a total of 1.27% of foraging habitat and 1.40% of breeding habitat in the study area.

Falco hypoleucos* (Grey Falcon) – *Endangered

The Grey Falcon is found throughout the arid and semi-arid zones of Australia. It is sparsely distributed in NSW, found chiefly throughout the Murray-Darling Basin, with the occasional vagrant east of the Great Dividing Range (OEH 2016b). The species has not been recorded in the study area.

The Grey Falcon is usually restricted to shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it has been found occasionally in open woodlands near the coast. The breeding range has contracted since the 1950s, with most breeding now confined to arid parts of its range where annual rainfall is less than 250 mm. The Grey Falcon utilises the old nests of other birds of prey and ravens, usually located high in a living eucalypt close to a watercourse; these may be dry during nesting. (OEH 2016b)It also occurs near wetlands, where surface water attracts prey (OEH 2016b). Within the study area, predicted habitat for the species includes water bodies, grassland and riparian woodland.

Within the study area, approximately 16,576 ha of habitat has been mapped which provides 16,576 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 75,759 ha of habitat has been mapped which provides 75,759 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 125.70 ha of foraging habitat would be directly impacted which equates to 0.76% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 9.88 ha of foraging habitat, which would combine to impact a total of 0.82%of foraging habitat in the study area.

Falco subniger* (Black Falcon) – *Vulnerable

The Black Falcon is widely but sparsely distributed in NSW, occurring mostly in inland regions. In New South Wales there is assumed to be a single population that is continuous with a broader continental population, given that falcons are highly mobile, commonly travelling hundreds of kilometres (Marchant & Higgins 1993). The species has been recorded within the north-west of the study area, with one record west of Bundock Creek and the second record along a roadside, east of Mollee Creek.

The Black Falcon inhabits woodland, shrubland and grassland in the arid and semi-arid zones, especially riparian woodland and agricultural land with scattered remnant trees (NSW Scientific Committee 2013). It is often associated with streams or wetlands, which it visits in search of prey. Black Falcons nest in the old stick nests of corvids or sometimes other raptor species. These tend to be located at the top of emergent trees in woodland, particularly riparian woodland (NSW Scientific Committee 2013). Within the study area, Black Falcon was observed in isolated trees surrounded by grassland. Predicted habitat in the study area for this species includes grassy woodland, heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland.

Within the study area, approximately 77,571 ha of habitat has been mapped which provides 77,571 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 334,319 ha of habitat has been mapped which provides 334,319 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 965.60 ha of habitat would be directly impacted (965.60 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.24% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 176.41 ha of habitat (176.41 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.47% of foraging habitat and 1.55% of breeding habitat in the study area.

Hamirostra melanosternon* (Black-breasted Buzzard) – *Vulnerable

The Black-breasted Buzzard has a sparse but widespread distribution, occurring in areas receiving less than 500 mm rainfall from north-western NSW and north-eastern South Australia to the east coast at about Rockhampton, then across northern Australia south almost to Perth, avoiding only the Western Australian deserts (OEH 2016b). The species has not been recorded within the study area.

The Black-breasted Buzzard lives in a range of inland habitats, including open forest, riverine woodland, scrub and heathland. It is often found along timbered watercourses which is its preferred breeding habitat (OEH 2016b). It may also hunt over grasslands and sparsely-timbered woodlands. In the eastern Pilliga, the Black-breasted Buzzard is known to utilise shrubby woodland, and is predicted to utilise all other habitat types present in the study area.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 7,011 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 35,020 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 49.80 ha of breeding habitat) which equates to 1.23% of foraging and 0.71% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 9.88 ha of breeding habitat) which would combine to impact a total of 1.45% of foraging habitat and 0.85% of breeding habitat in the study area.

Hieraaetus morphnoides* (Little Eagle) – *Vulnerable

The Little Eagle is found throughout the Australian mainland, with the exception of the most densely-forested parts of the Dividing Range escarpment (Marchant & Higgins 1993). It occurs as a single population throughout NSW (OEH 2016b). The Little Eagle was recorded in the very north of the study area along Yarrie Lake Road and just to the east of the study area. There are previous records within the study area along Yarrie Lake Road and Bohena Creek (OEH 2016a).

The Little Eagle occurs in prey-rich habitats in open eucalypt forest, woodland or open woodland, extending into the arid zone. It tends to avoid rainforest and heavy forest (OEH 2016b). In inland NSW, Sheoak and Acacia woodland and riparian woodland are utilised (Marchant & Higgins 1993). For nesting, the species favours tall living trees in remnant habitat, where a large stick nest is built in winter. In the eastern Pilliga, the Little Eagle has been recorded utilising grassy woodland and shrub-grass woodland habitats. In the study area it is predicted to also utilise water bodies, grassland, heathy woodland, riparian woodland and shrubby woodland.

Within the study area, approximately 76,270 ha of habitat has been mapped which provides 76,270 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 326,737 ha of habitat has been mapped which provides 326,737 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 937.70 ha of habitat would be directly impacted (937.70 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.23% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.45% of foraging habitat and 1.55% of breeding habitat in the study area.

Lophoictinia isura* (Square-tailed Kite) – *Vulnerable

The Square-tailed Kite occurs in coastal and subcoastal areas from south-western to northern Australia, Queensland, NSW and Victoria. In NSW, there are scattered records of the species throughout the state, indicating that it is a regular resident in the north, north-east and along the major west-flowing river systems (OEH 2016b). It is a summer breeding migrant to the south-east, including the NSW south coast, from September to March. The Square-tailed kite has been recorded during surveys within the study area along Bohena Creek and in the north-west hunting over cleared land adjacent to Bundock Creek.

The species is found in a variety of timbered habitats including dry woodlands and open forests, with a particular preference for timbered watercourses. In inland Australia, it favours Box-Ironbark-Gum woodlands on the slopes, and Coolibah/River Red Gum on the plains (Marchant & Higgins 1993). Nest sites are generally located along or near watercourses, in open forest, woodland or forest edges (OEH 2016b). Within the eastern Pilliga, the species is known to use heathy woodland, shrubby woodland, riparian woodland and grassland habitats; it is predicted to also utilise grassy woodland and shrub-grass woodland in the study area.

Within the study area, approximately 76,270 ha of habitat has been mapped which provides 76,270 ha of foraging habitat and 7,011 ha of breeding habitat. Within the study region, approximately 326,737 ha of habitat has been mapped which provides 326,737 ha of foraging habitat and 35,020 ha of breeding habitat. An upper limit of 937.70 ha of habitat would be directly impacted (937.70 ha of foraging habitat and 49.80 ha of breeding habitat) which equates to 1.23% of foraging and 0.71% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (170.71 ha of foraging habitat and 9.88 ha of breeding habitat) which would combine to impact a total of 1.45% of foraging habitat and 0.85% of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Spotted Harrier, Grey Falcon, Black Falcon, Black-breasted Buzzard, Little Eagle or Square-tailed Kite at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

The Grey Falcon does do not have breeding habitat in the study area as their known breeding range is in the arid zone. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the six assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by identification and minimising removal of large stick nests, staged construction, progressive rehabilitation, reducing the removal of hollow-bearing trees (suitable for prey species) and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would directly remove the following amount of breeding and foraging habitat for the six assessed species:

- Spotted Harrier: 498.70 ha of habitat (498.70 ha of foraging habitat and 422.80 ha of breeding habitat). This constitutes approximately 1.09% of foraging habitat and 1.17% of breeding habitat in the study area.
- Grey Falcon: 125.70 ha of foraging habitat which constitutes approximately 0.76% of foraging habitat in the study area.

- Black Falcon: 965.60 ha of habitat (965.60 ha of foraging habitat and 861.80 ha of breeding habitat). This constitutes approximately 1.24% of foraging habitat and 1.29% of breeding habitat in the study area.
- Black-breasted Buzzard: 988.80 ha of habitat (988.80 ha of foraging habitat and 49.80 ha of breeding habitat). This constitutes approximately 1.23% of foraging habitat and 0.71% of breeding habitat in the study area.
- Little Eagle: 937.70 ha of habitat (937.70 ha of foraging habitat and 861.80 ha of breeding habitat). This constitutes approximately 1.23% of foraging habitat and 1.29% of breeding habitat in the study area.
- Square-tailed Kite: 937.70 ha of habitat (937.70 ha of foraging habitat and 49.80 ha of breeding habitat). This constitutes approximately 1.23% of foraging habitat and 0.71% of breeding habitat in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss the following amounts of foraging and breeding habitat for the six assessed species:

- Spotted Harrier: 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.27% of foraging habitat and 1.40% of breeding habitat in the study area.
- Grey Falcon: 9.88 ha of foraging habitat which combines with direct impacts to constitute a total impact of 0.82% of foraging habitat in the study area.
- Black Falcon: 176.41 ha of habitat (176.41 ha of foraging habitat and 170.71 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.47% of foraging habitat and 1.55% of breeding habitat in the study area.
- Black-breasted Buzzard: 181.11 ha of habitat (181.11 ha of foraging habitat and 9.88 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat and 0.85% of breeding habitat in the study area.
- Little Eagle: 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat and 1.55% of breeding habitat in the study area.
- Square-tailed Kite: 170.71 ha of habitat (170.71 ha of foraging habitat and 9.88 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat and 0.85% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the six assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the six assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the six assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the six assessed species in the study region (the locality).

The habitat to be directly or indirectly impacted provides foraging and breeding habitat for the six assessed species (except for Grey Falcon which would not breed in the study area). The study area would still maintain over 98% of habitat for the six assessed species which could continue to support foraging and breeding (except for Grey Falcon) in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Mitigation measures recommending avoidance of large stick nests and minimising impacts along riparian areas would insure that impact to important habitat features is minimised. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the six assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

A recovery plan has not been written for the six assessed species. No threat abatement plan is relevant to the six assessed species.

Under the Saving our Species program, Spotted Harrier, Black Falcon, Black-breasted Buzzard, Little Eagle and Square-tailed Kite have been assigned as landscape species and Grey Falcon has been assigned as a data-deficient species. A species action statement has been prepared for each of these species and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Spotted Harrier and have been discussed in relation to the project:

1. *Raise awareness about poisoning of non-target species from baiting and rodenticides*. The feral animal control strategy proposed as part of the project would use baiting as a control technique. Poisoning of non-target species would be addressed in the program design and monitoring phases.

The following management actions are applicable for Grey Falcon and have been discussed in relation to the project:

1. *Educate and encourage landholders to protect and rehabilitate riparian habitat and implement grazing regimes that create or protect large areas of good quality habitat to enhance the prey biomass.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would

avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers).

2. *Ensure implementation of management strategies that reduce disturbance of riparian areas.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers).

The following management actions are applicable for Black Falcon and have been discussed in relation to the project:

1. *Protect old stick nests (e.g. those of corvids and raptors) that have the potential to be used as nest sites.* Nests are recorded as part of the pre-clearing procedure and removal of trees with nests would be avoided or minimised through the scouting procedure.
2. *Protect and facilitate the recruitment of large old trees, a resource that is critical for nesting and hunting.* Over 98% of foraging and breeding habitat in the study area would be retained and the recruitment of additional hollows would be possible in these areas.
3. *Protect and expand potential nesting habitat, especially riparian and floodplain woodlands.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers).
4. *Promote the reporting of any signs of disease that are unusual or clusters of deaths in raptors or their prey to the NSW Environment Line on 131 555.* Records of the Black Falcon would be supplied to OEH under the OEH licence agreement. If signs of disease are observed during the biodiversity monitoring proposed to be undertaken as part of the project, this information would be supplied.

The following management actions are applicable for Black-breasted Buzzard and have been discussed in relation to the project:

1. *Educate and encourage landholders to protect and rehabilitate riparian habitat and implement grazing regimes that create or protect large areas of good quality habitat to enhance the prey biomass.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers).
2. *Implement management strategies that reduce disturbance of riparian areas.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers)

The following management actions are applicable for Little Eagle and have been discussed in relation to the project:

1. *Raise awareness about poisoning of non-target species from baiting and rodenticides*. The feral animal control strategy proposed as part of the project would use baiting as

a control technique. Poisoning of non-target species would be addressed in the program design and monitoring phases.

2. *Identify and secure appropriate habitat and improve management by erecting fences, adding supplementary planting, managing or reducing grazing, increasing size of habitat patches, planting stepping-stone linking patches and encourage the retention or placement of fallen logs, coarse woody debris and standing dead trees.* Habitat has been identified and mapped in the study area. Fallen logs and standing dead trees are recorded during pre-clearing surveys and impact would be avoided or minimised through the ecological scouting framework. Rehabilitation would include the placement of fallen logs as habitat features.

The following management actions are applicable for Square-tailed Kite and have been discussed in relation to the project:

1. *Ensure implementation of management strategies that reduce disturbance of riparian areas.* Riparian habitat has been identified and mapped in the study area. Riparian buffers have been mapped and infrastructure positioning would avoid or minimise impact to riparian buffer (no well pads would be located in riparian buffers but gathering system may cross riparian buffers).

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the six assessed species:

- Direct impact
  - Clearing of native vegetation
  - Removal of hollow-bearing trees (supports prey populations)
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Spotted Harrier, Grey Falcon, Black Falcon, Black-breasted Buzzard, Little Eagle or Square-tailed Kite. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Spotted Harrier, Grey Falcon, Black Falcon, Black-breasted Buzzard, Little Eagle or Square-tailed Kite.

Woodland birds – large ground foraging

Ardeotis australis (Australian Bustard) and *Burhinus grallarius* (Bush Stone-curlew) are considered in this assessment.

Ardeotis australis* (Australian Bustard) – *Endangered

The Australian Bustard mainly occurs in inland Australia, and is now scarce or absent from southern and south-eastern Australia. In NSW, they are mainly found in the north-west and less frequently in the lower western and central west plains regions. Occasional vagrants are still seen as far east as the western slopes and riverine plains. Breeding now only occurs in the north-west region of NSW (OEH 2016b). It is known to occur within the Pilliga and Liverpool Plains sub-regions of the Namoi catchment but there are no records within the study area (OEH 2016b). A recent sighting was recorded on July 2014 in open grassy paddock on private property north of the study area (Birdlife Australia 2014).

The species mainly inhabits tussock and hummock grasslands, preferring the former to the latter. It also occurs in low shrublands and low open grassy woodlands, and is occasionally seen in pastoral and cropping country, golf courses and near dams (OEH 2016b). Nesting habitat comprises bare ground on low sandy ridges or stony rises, in ecotones between grassland and protective shrubland cover. It roosts on the ground among shrubs and long grasses or under trees. Predicted habitat for the species within the study area includes water bodies and grassland.

Within the study area, approximately 9,565 ha of habitat has been mapped which provides 9,565 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 40,739 ha of habitat has been mapped which provides 40,739 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 75.90 ha of foraging habitat would be directly impacted which equates to 0.79% of foraging habitat directly impacted in the study area. No additional foraging or breeding habitat would be indirectly impacted in the study area.

Burhinus grallarius* (Bush Stone-curlew) – *Endangered

The Bush Stone-curlew is found throughout mainland Australia, with the exception of the central southern coast and inland, and the far south-east corner. Only in northern Australia is it still common; in the south-east it is either rare or extinct throughout its former range (OEH 2016b). In NSW it is now found sporadically in coastal areas, and west of the divide throughout the sheep-wheat belt (DEC 2006b). The species has not been recorded within the study area (OEH 2016a).

In NSW, the Bush Stone-curlew occurs in lowland grassy woodland and open forest (DEC 2006b). West of the Great Dividing Range, Bush Stone-curlews are associated with *Eucalyptus microcarpa* (Grey Box), *E. camaldulensis* (River Red Gum), *E. largiflorens* (Black Box) and *E. melliodora* (Yellow Box), with a sparse ground cover of native grasses and few or no shrubs (Marchant & Higgins 1993; Johnson & Baker-Gabb 1994). They also occasionally occur in box-ironbark forests and patches of *Allocasuarina* spp. (She-oak). Within the eastern Pilliga, Bush stone-curlews are known to utilise grassy woodland and shrub-grass woodland habitats. In the study area grassland and riparian woodland are further predicted habitat for the species in the area.

The Bush Stone-curlew has different specific habitat requirements for foraging, roosting and nesting, and the proximity of suitable areas for each activity is likely to influence the abundance and distribution the species (DEC 2006b). It forages nocturnally in areas with fallen timber, leaf litter and little undergrowth (Garnett & Crowley 2000; Marchant & Higgins 1993). This may include irrigated paddocks, grasslands, woodlands, domestic gardens, saltmarsh, mangroves, and playing fields (DEC 2006b). It roosts during the day in or near woodland remnants amongst fallen timber or ground litter (Johnson & Baker-Gabb 1994). The nest site is typically in or near the edge of open grassy woodland or within a cleared paddock.

Within the study area, approximately 45,563 ha of habitat has been mapped which provides 45,563 ha of foraging habitat and 36,098 ha of breeding habitat. Within the study region, approximately 245,413 ha of habitat has been mapped which provides 245,413 ha of foraging habitat and 211,106 ha of breeding habitat. An upper limit of 498.70 ha of habitat would be directly impacted (498.70 ha of foraging habitat and 422.80 ha of breeding habitat) which equates to 1.09% of foraging and 1.17% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat) which would combine to impact a total of 1.28% of foraging habitat and 1.40% of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Australian Bustard or Bush Stone-curlew at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

The Australian Bustard does not have breeding habitat in the study area. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the two assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 75.90 ha of foraging habitat for Australian Bustard. Up to 498.70 ha of habitat for Bush Stone-curlew would be removed, which provides 498.70 ha of foraging habitat and 422.80 ha of breeding habitat. This constitutes approximately 0.79% of foraging habitat for Australian Bustard and 1.09% of foraging habitat and 1.17% of breeding habitat for Bush Stone-curlew removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 83.25 ha of habitat for Bush Stone-curlew which provides 83.25 ha of foraging habitat and 83.25 ha of breeding habitat. The direct and indirect impact on Bush Stone-curlew habitat would constitute a total impact of approximately 1.28% of foraging habitat and 1.40% breeding habitat in the study area.

No additional Australian Bustard foraging habitat would be indirectly impacted.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the two assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the two assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the two assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the two assessed species in the study region (the locality).

The habitat to be directly or indirectly impacted provides potential foraging habitat for the two assessed species and potential breeding habitat for Bush Stone-curlew. The study area would still maintain over 98% of habitat for the two assessed species which could continue to support foraging and breeding (for Bush Stone-curlew) in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the two assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

An approved recovery plan for the Bush Stone-curlew has been prepared (DEC 2006b). Recovery objectives relevant to the project are provided below with description on how they have been addressed:

1. *Increase the total area of Bush Stone-curlew habitat protected and managed for conservation on public and private lands by 25% in each CMA*. Suitable foraging and breeding habitat has been identified and mapped in the study area. Threats to current occupation of the study area have been identified and would be managed (in particular, feral animal control, retention of fallen timber, weed management and use of chemicals).

2. *Ensure that impacts on Bush Stone-curlews and their habitat are accurately assessed during planning and environmental assessment processes*. Bush Stone-curlew and potential habitat in the study area has been assessed for this ecological assessment. No individuals were recorded in the study area but their potential occurrence in the

study area has been addressed.

Under the Saving our Species program, Australian Bustard is has been assigned as a partnership species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007). The following management actions are applicable for Australian Bustard and have been discussed in relation to the project:

1. *Educate landholders to not spread poison baits for rabbits when there are bustards present in an area.* The feral animal control strategy proposed as part of the project would use baiting as a control technique. Poisoning of non-target species would be addressed in the program design and monitoring phases.

2. *Conduct fox control throughout the species range.* The feral animal control strategy proposed as part of the project would include fox as a target species.

Predation by foxes is listed as a threat for both assessed species (OEH 2016b). Hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to these species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation.

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species.

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes.

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the two assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)

  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Removal of dead wood and dead trees (Bush Stone-curlew only).
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for these species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Australian Bustard or Bush Stone-curlew. The direct and indirect impact of less than 2% of the foraging and breeding (Bush Stone-curlew only) habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Australian Bustard or Bush Stone-curlew.

Woodland birds – ground and mid-storey foraging (passerines)

Artamus cyanopterus cyanopterus (Dusky Woodswallow), *Chthonicola sagittata* (Speckled Warbler), *Daphoenositta chrysoptera* (Varied Sittella), *Melanodryas cucullata cucullata* (Hooded Robin), *Pachycephala inornata* (Gilbert's Whistler), *Petroica boodang* (Scarlet Robin), *Pomatostomus temporalis temporalis* (Grey-crowned Babbler) and *Stagonopleura guttata* (Diamond Firetail) are considered in this assessment.

***Artamus cyanopterus cyanopterus* (Dusky Woodswallow) – Vulnerable**

The Dusky Woodswallow has two separate populations, with the eastern population extending from the Atherton Tableland in Queensland, south to Tasmania and west to Eyre Peninsula in South Australia. Within this region it is widespread from the coast to inland, including the western slopes of the Great Dividing Range and farther west (Higgins & Peter 2002).

The Dusky Woodswallow occupies a range of habitats in woodlands and dry open sclerophyll forests, usually dominated by eucalypts. It has also been recorded in shrublands and heathlands and various modified habitats including regenerating forests (Higgins & Peter 2002). Despite the wide distribution and occurrence in a variety of habitats, it is considered a woodland dependent bird with the majority of breeding records and records during the breeding season on the western slopes of the Great Dividing Range (NSW Scientific Committee 2015). In the study area, the species has been recorded in grassy woodland, riparian woodland and shrub grass woodland and is also predicted to occur in water bodies, grassland, heath, heathy woodland and shrubby woodland.

Within the study area, approximately 77,671 ha of habitat has been mapped which provides 77,671 ha of foraging habitat and 68,106 ha of breeding habitat. Within the study region, approximately 340,751 ha of habitat has been mapped which provides 340,751 ha of foraging habitat and 300,013 ha of breeding habitat. An upper limit of 965.60 ha of habitat would be directly impacted (965.60 ha of foraging habitat and 889.70 ha of breeding habitat) which equates to 1.24% of foraging and 1.31% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 176.41 ha of habitat (176.41 ha of foraging habitat and 176.41 ha of breeding habitat) which would combine to impact a total of 1.47% foraging habitat and 1.56% breeding habitat in the study area.

Chthonicola sagittata* (Speckled Warbler) – *Vulnerable

The Speckled Warbler has a patchy distribution throughout south-eastern Queensland, the eastern half of NSW and into Victoria, as far west as the Grampians. It occurs most frequently in the hills and tablelands of the Great Dividing Range, and rarely on the coast. There has been a decline in population density throughout its range, with the decline exceeding 40% where no vegetation remnants larger than 100 ha survive (OEH 2016b). The Speckled Warbler has been recorded throughout the study area and previous records are throughout the Pilliga (OEH 2016a).

The Speckled Warbler occupies a wide range of eucalypt-dominated communities with a grassy understorey, often on rocky ridges or in gullies (OEH 2016b). Typical habitat includes scattered native tussock grasses, a sparse shrub layer, some eucalypt regrowth and an open canopy. Large, relatively undisturbed remnants are required for the species to persist in an area (OEH 2016b). A nest is built either in a slight hollow in the ground or in the base of a low dense plant, often among fallen branches and other litter. In the eastern Pilliga, the species is known to utilise water bodies, grasslands, grassy woodlands, heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitat types.

Within the study area, approximately 45,663 ha of habitat has been mapped which provides 45,663 ha of foraging habitat and 36,098 ha of breeding habitat. Within the study region, approximately 251,845 ha of habitat has been mapped which provides 251,845 ha of foraging habitat and 211,106 ha of breeding habitat. An upper limit of 498.70 ha of habitat would be directly impacted (498.70 ha of foraging habitat and 422.80 ha of breeding habitat) which equates to 1.09% of foraging and 1.17% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat) which would combine to impact a total of 1.27% foraging habitat and 1.40% breeding habitat in the study area.

Daphoenositta chrysoptera* (Varied Sittella) – *Vulnerable

The Varied Sittella is widespread in mainland Australia in most areas other than treeless deserts and grasslands. Its distribution in NSW is nearly continuous from the coast to the far west, but it appears to have undergone a moderate reduction in population size over the past few decades (OEH 2016b). The species has been recorded throughout the study area and previous records are throughout the Pilliga (OEH 2016a).

The Varied Sittella is found in woodlands and forests, exhibiting a preference for rough-barked trees like stringybarks and ironbarks, mature trees with hollows or dead branches and mallee and Acacia woodland (OEH 2016b). In the eastern Pilliga, it is known to utilise grassy woodland, heathy woodland, riparian woodland and shrubby woodland habitats; further predicted habitat for the species in the study area includes closed forest and shrub-grass woodland.

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27%of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.53% of both foraging and breeding habitat in the study area.

Melanodryas cucullata cucullata* (Hooded Robin, south-eastern form) – *Vulnerable

The Hooded Robin is widespread but uncommon across most of mainland Australia, except for the driest deserts and the wetter coastal areas. The south-eastern form (subspecies *cucullata*) occurs from Brisbane to Adelaide and throughout much of inland NSW, with the exception of the extreme north-west, where it is replaced by subsp. *picata* (OEH 2016b). The species has been recorded from a range of locations within the study area and previous records are throughout the Pilliga (OEH 2016a).

The Hooded Robin is associated with eucalypt woodlands, acacia shrublands and open forests (OEH 2016b). It requires structurally diverse habitats with a sparse understorey, some grassy areas and a complex ground layer (NSW Scientific Committee 2008a). In the eastern Pilliga, the species is known to utilise grassland, heathy woodland, riparian woodland and shrub-grass woodland habitats, and is predicted to also use water bodies, grassy woodlands, heath and shrubby woodlands in the study area.

Within the study area, approximately 77,671 ha of habitat has been mapped which provides 77,671 ha of foraging habitat and 68,106 ha of breeding habitat. Within the study region, approximately 340,751 ha of habitat has been mapped which provides 340,751 ha of foraging habitat and 300,013 ha of breeding habitat. An upper limit of 965.60 ha of habitat would be directly impacted (965.60 ha of foraging habitat and 889.70 ha of breeding habitat) which equates to 1.24% of foraging and 1.31% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 176.41 ha of habitat (176.41 ha of foraging habitat and 176.41 ha of breeding habitat) which would combine to impact a total of 1.47% foraging habitat and 1.56% breeding habitat in the study area.

Pachycephala inornata* (Gilbert's Whistler) – *Vulnerable

Gilbert's Whistler is sparsely distributed over much of the arid and semi-arid zone of inland southern Australia, from the western slopes of NSW to the Western Australian wheatbelt. The eastern population extends from the central NSW mallee, south and east through the Cocoparra Range to Pomingalama Reserve (near Wagga Wagga) then north through the South West Slopes, east as far as Cowra and Burrendong Dam to the Goonoo reserves (with scattered records as far north as Pilliga; OEH 2014b). This species has been recorded within the Pilliga and Pilliga Outwash sub-regions of the Namoi Catchment (OEH 2016b). It is not known to occur in the study area.

This species occurs in timbered arid and semi-arid habitats, especially mallee shrubland, and occasionally in box-ironbark woodlands, Cypress Pine and Belah woodlands and River Red Gum forests (although it has only been recorded using the latter along the Murray, Edwards and Wakool Rivers; OEH 2014b). The woodland habitats utilised by the species contain areas of dense shrubbery in the understorey (OEH 2016b). In the eastern Pilliga, Gilbert's Whistler is known to utilise shrubby woodland habitats. Other predicted habitat in the study area includes closed forest, water bodies, grassy woodland, heathy woodland, riparian woodland and shrub-grass woodland.

Within the study area, approximately 69,632 ha of habitat has been mapped which provides 69,632 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 308,870 ha of habitat has been mapped which provides 308,870 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.52% of foraging habitat and 1.53% of breeding habitat in the study area.

Petroica boodang* (Scarlet Robin) – *Vulnerable

The Scarlet Robin is found from south-east Queensland to south-east South Australia, Tasmania and south-western Western Australia. In NSW, it occurs from the coast to the inland slopes (Higgins & Peter 2002). After breeding, some Scarlet Robins disperse to the lower valleys and plains of the tablelands and slopes. Some birds may appear as far west as the eastern edges of the inland plains in autumn and winter (OEH 2016b). This species has been recorded within the Pilliga and Pilliga Outwash sub-regions of the Namoi Catchment (OEH 2016b). It is not known to occur in the study area.

The Scarlet Robin is primarily a resident of drier eucalypt forests and temperate woodlands, often on ridges and slopes, with an open grassy understorey and scattered shrubs. An abundance of logs and fallen timber is an important structural component of its habitat (OEH 2016b). In autumn and winter it migrates to more open habitats such as grassy open woodland or paddocks with scattered trees (NSW Scientific Committee 2010). Predicted habitat for the species in the study area includes water bodies, grassland, grassy woodland, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland.

Within the study area, approximately 76,270 ha of habitat has been mapped which provides 76,270 ha of foraging habitat and 66,705 ha of breeding habitat. Within the study region, approximately 326,737 ha of habitat has been mapped which provides 326,737 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 937.70 ha of habitat would be directly impacted (937.70 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.23% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.45% foraging habitat and 1.55% breeding habitat in the study area.

Pomatostomus temporalis temporalis (Grey-crowned Babbler, eastern subspecies) – _Vulnerable_

The Grey-Crowned Babbler (eastern subspecies) is distributed from Cape York south through Queensland, NSW and Victoria. In NSW, the eastern sub-species occurs on the western slopes of the Great Dividing Range, and as far as Louth and Balranald on the western plains. It also occurs in woodlands in the Hunter Valley and in some locations on the north coast (OEH 2016b). This species has been recorded extensively throughout the study area and previous records are extensive throughout the Pilliga (OEH 2016a).

This species is found in open woodland habitats dominated by mature eucalypts, with regenerating trees, tall shrubs, and an intact ground cover of grass and forbs (NSW Scientific Committee 2001). It avoids very wet areas (Blakers et al. 1984). The Grey-crowned Babbler favours Box-gum woodlands on the slopes and Box-cypress and open Box woodlands on alluvial plains (OEH 2016b). In the study area, the species has been recorded utilising all habitat types (closed forest, water bodies, grasslands, grassy woodlands, heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland).

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.45%foraging habitat and 1.53% breeding habitat in the study area.

Stagonopleura guttata (Diamond Firetail) – _Vulnerable_

The Diamond Firetail is endemic to south-eastern Australia, its distribution extending from central Queensland to the Eyre Peninsula in South Australia (OEH 2016b). It is widely distributed in NSW, with most records from the Northern, Central and Southern Tablelands, the Northern, Central and South Western Slopes and the North West Plains and Riverina. It is not commonly found in coastal districts, though there are records from western Sydney, the Hunter Valley and the Bega Valley (Blakers et al. 1984; Schodde & Mason 1999). The Diamond Firetail has been recorded at multiple locations along Bohena Creek and in areas of forest to grassland ecotone in the north of the study area.

The species is typically found in grassy eucalypt woodlands, but also occurs in open forest, mallee, Natural Temperate Grassland, and in secondary grassland derived from other communities (OEH 2016b). It is often found in riparian areas and sometimes in lightly wooded farmland. In the eastern Pilliga, the species is known from water bodies, grassland, riparian woodland and shrub-grass woodland habitats. In the study area it is predicted to also utilise grassy woodlands.

Within the study area, approximately 45,663 ha of habitat has been mapped which provides 45,663 ha of foraging habitat and 36,098 ha of breeding habitat. Within the study region, approximately 251,845 ha of habitat has been mapped which provides 251,845 ha of foraging habitat and 211,106 ha of breeding habitat. An upper limit of 498.70 ha of habitat would be directly impacted (498.70 ha of foraging habitat and 422.80 ha of breeding habitat) which equates to 1.09% of foraging and 1.17% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat) which would combine to impact a total of 1.27% foraging habitat and 1.40% breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Dusky Woodswallow, Speckled Warbler, Hooded Robin, Gilbert's Whistler, Scarlet Robin, Grey-crowned Babbler or Diamond Firetail at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the seven assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would directly remove the following amount of breeding and foraging habitat for the seven assessed species:

- Dusky Woodswallow: 965.60 ha of habitat (965.60 ha of foraging habitat and 889.70 ha of breeding habitat). This constitutes approximately 1.24% of foraging habitat and 1.31% of breeding habitat in the study area.
- Speckled Warbler: 498.70 ha of habitat (498.70 ha of foraging habitat and 422.80 ha of breeding habitat). This constitutes approximately 1.09% of foraging habitat and 1.17% of breeding habitat in the study area.
- Varied Sittella: 885.00 ha of habitat (885.00 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.27% of foraging habitat and 1.27% of breeding habitat in the study area.
- Hooded Robin: 965.60 ha of habitat (965.60 ha of foraging habitat and 889.70 ha of breeding habitat). This constitutes approximately 1.24% of foraging habitat and 1.31% of breeding habitat in the study area.
- Gilbert's Whistler: 885.00 ha of habitat (885.00 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.27% of foraging habitat and 1.27% of breeding habitat in the study area.
- Scarlet Robin: 937.70 ha of habitat (937.70 ha of foraging habitat and 861.80 ha of breeding habitat). This constitutes approximately 1.23% of foraging habitat and 1.29% of breeding habitat in the study area.
- Grey-crowned Babbler: 988.80 ha of habitat (988.80 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.23% of foraging habitat and 1.27% of breeding habitat in the study area.
- Diamond Firetail: 498.70 ha of habitat (498.70 ha of foraging habitat and 422.80 ha of breeding habitat). This constitutes approximately 1.09% of foraging habitat and 1.17% of breeding habitat in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss the following amounts of foraging and breeding habitat for the seven assessed species:

- Dusky Woodswallow: 176.41 ha of habitat (176.41 ha of foraging habitat and 176.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.47% of foraging habitat and 1.57% of breeding habitat in the study area.
- Speckled Warbler: 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.27% of foraging habitat and 1.40% of breeding habitat in the study area.
- Varied Sittella: 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.53% of foraging habitat and 1.53% of breeding habitat in the study area.
- Hooded Robin: 176.41 ha of habitat (176.41 ha of foraging habitat and 176.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.47% of foraging habitat and 1.57% of breeding habitat in the study area.
- Gilbert's Whistler: 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.52% of foraging habitat and 1.53% of breeding habitat in the study area.
- Scarlet Robin: 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat and 1.55% of breeding habitat in the study area.
- Grey-crowned Babbler: 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat and 1.53% of breeding habitat in the study area.
- Diamond Firetail: 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.27% of foraging habitat and 1.40% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the seven assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the seven assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the seven assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the seven assessed species in the study region (the locality).

The habitat to be directly or indirectly impacted provides foraging and breeding habitat for the seven assessed species. The study area would still maintain over 98% of habitat for the seven assessed species which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the seven assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program Speckled Warbler, Varied Sittella, Hooded Robin, Gilbert's Whistler, Scarlet Robin, Grey-crowned Babbler and Diamond Firetail have all been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

For Dusky Woodswallow, the priory actions have not yet been published due to the recent listing of the species (August 2016). Those actions that are relevant to the other assessed woodland birds are considered to be supportive of Dusky Woodswallow conservation in the study area.

The following relevant management actions are applicable for Speckled Warbler and have been discussed in relation to the project:

1. *Conduct ecological research to determine habitat and resource requirements, threats and conservation issues.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat, known and possible threats and actions for long-term conservation of the species in the study area.

None of the management actions for Varied Sittella are relevant to the project.

The following relevant management actions are applicable for Hooded Robin and have been discussed in relation to the project:

1. *Conduct ecological research to determine habitat and resource requirements, threats and conservation issues.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat, known and possible threats and actions for long-term conservation of the species in the study area.

The following relevant management actions are applicable for Gilbert's Whistler and have been discussed in relation to the project:

1. *Using current records and literature on habitat requirements determine the current distribution and identify areas of potential habitat to undertake survey and management actions.* No records for Gilbert's Whistler were recorded during surveys for this ecological assessment. Areas of potential foraging and breeding habitat have been identified and mapped. Records obtained during biodiversity monitoring proposed to be undertaken as part of the project would be supplied to OEH under the OEH licence agreement.

The following relevant management actions are applicable for Scarlet Robin and have been discussed in relation to the project:

1. *Identify and secure appropriate habitat and improve management by erecting fences, adding supplementary planting, managing or reducing grazing, increasing size of habitat patches, planting stepping-stone linking patches and encourage the retention or placement of fallen logs, coarse woody debris and standing dead trees.* Habitat has been identified and mapped in the study area. Fallen logs and standing dead trees are recorded during pre-clearing surveys and impact would be avoided or minimised through the ecological scouting framework. Rehabilitation would include the placement of fallen logs as habitat features.

2. *Implement feral cat control at priority sites.* The feral animal control strategy proposed as part of the project would include feral cats as a target species.

The following relevant management actions are applicable for Grey-crowned Babbler and have been discussed in relation to the project:

1. *Conduct ecological research to determine habitat and resource requirements, threats and conservation issues.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat, known and possible threats and actions for long-term conservation of the species in the study area.

The following relevant management actions are applicable for Diamond Firetail and have been discussed in relation to the project:

1. *Conduct ecological research to determine habitat and resource requirements, threats and conservation issues.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat, known and possible threats and actions for long-term conservation of the species in the study area.

Predation by foxes is listed as a threat for all assessed species (OEH 2016b). Hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to these species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation.

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species.

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes.

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the seven assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for these species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Dusky Woodswallow, Speckled Warbler, Varied Sittella, Hooded Robin, Gilbert's Whistler, Scarlet Robin, Grey-crowned Babbler or Diamond Firetail. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Dusky Woodswallow, Speckled Warbler, Varied Sittella, Hooded Robin, Gilbert's Whistler, Scarlet Robin, Grey-crowned Babbler or Diamond Firetail.

Woodland birds – canopy foraging (excluding parrots)

Anthochaera phrygia (Regent Honeyeater), *Grantiella picta* (Painted Honeyeater) and *Melithreptus gularis gularis* (Black-chinned Honeyeater) are considered in this assessment.

Anthochaera phrygia* (Regent Honeyeater) – *Critically Endangered

The Regent Honeyeater has an extremely patchy distribution across the inland slopes of south-east Australia between north-eastern Victoria and south-eastern Queensland (OEH 2016b). Birds are also found in drier coastal woodlands and forests in some years. In NSW, most records are from the Great Dividing Range, mainly on the North-West Plains, North-West and South-West Slopes, Northern Tablelands, Central Tablelands and Southern Tablelands regions; as well as the Central Coast and Hunter Valley regions. Regent Honeyeaters have been recorded sporadically in the Pilliga (in 1991, 1992, 1997 and 2003; OEH 2014a). Their distribution in the Pilliga may fluctuate based on fluctuations of eucalypt flowering, including *E. albens* beyond the Pilliga. Minor and sporadic breeding occurs in Warrumbungle National Park, Pilliga Nature Reserve and Mudgee-Wollar region (Garnett et al. 2011; OEH 2016b).

Regent Honeyeaters are associated with temperate eucalypt woodland and open forest including forest edges, wooded farmland and urban areas with mature eucalypts, and riparian forests of *Casuarina cunninghamiana* (River Oak) (Garnett 1993). The Regent Honeyeater primarily feeds on nectar from box and ironbark eucalypts and occasionally from banksias and mistletoes. As such it is reliant on locally abundant nectar sources with different flowering times to provide reliable supply of nectar (Garnett & Crowley 2000). Insects make up about 15% of the species' total diet, and lerp and honeydew are important when nectar is scarce (OEH 2016b).

The Warrumbungles, Pilliga Nature Reserve and adjoining habitat to the south of the development site has been mapped as 'other breeding areas' that support the key breeding area of Bundarra-Barraba in the National Recovery Plan (DotE 2016a). A coarse-scale map provided in the National Recovery Plan was digitised and overlayed with the development site boundary. The 'other breeding area' mapped in the Pilliga overlays with approximately 2,755 ha (2.90%) of the development site in the south-eastern corner. The vegetation communities mapped in this area are predominantly PCTs 404, 405 and 406 which are shrubby and heathy woodlands. They are not associated with drainage lines and don't support local preferred flowering Eucalypt species. At a site-scale, this habitat is not considered preferred breeding habitat for Regent Honeyeater.

The species is considered to have the potential to occur in the study area. Previous sightings of Regent Honeyeaters in the Pilliga Forest have been largely associated with drainage lines (OEH 2016a). They are mostly observed in Box – Ironbark Eucalypt woodland and dry sclerophyll forest associations, and are known to prefer more fertile habitats along drainage lines, in broad river valleys and foothills. Eucalypts that reliably produce large amounts of nectar occurring in the Pilliga are *E. sideroxylon*, *E. melliodora* (Yellow Box) and *E. albens* (White Box). In particular, areas of *E. sideroxylon* X *melliodora* hybrid and *E. sideroxylon* occur in the study area. Other eucalypt associations that occur in the Pilliga are *E. blakelyi* (Blakely's Red Gum), *E. melanophloia* (Silver-leaved Ironbark), *E. crebra* (Narrow-leaved Ironbark) and *Angophora floribunda* (Rough-barked Apple). Loss of habitat also forces Regent Honeyeaters to use less productive habitat.

Within the study area, approximately 57,579 ha of potential habitat has been mapped which provides 57,579 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 246,370 ha of habitat has been mapped which provides 246,370 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 796.80 ha of potential foraging habitat would be directly impacted which equates to 1.38% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 157.48 ha of habitat which would combine to impact a total of 1.66% of foraging habitat in the study area.

Grantiella picta* (Painted Honeyeater) – *vulnerable

The Painted Honeyeater occurs in the eastern half of Australia, from the eastern Northern Territory, through Queensland, New South Wales and Victoria to south-eastern South Australia (DSE 2003). It occurs predominantly on the inland side of the Great Dividing Range but avoids arid areas (Blakers et al. 1984). It is a nomadic species and occurs at low densities throughout its range. The greatest concentrations of the bird (and almost all breeding), occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. During the winter it is more likely to be found in the north of its distribution, in the semi-arid woodlands of inland and northern Australia (OEH 2016b). The species has been observed at two locations in the west of the study area, near Bundock Creek within Pilliga East State Forest. It was also recorded in the east of the study area near a tributary to Spring Creek and just outside the eastern edge of the study area. Previous records of the species are concentrated in the north-west of the study area, including Yarrie Lake, in and around Brigalow Nature Reserve and Brigalow State Conservation Area (OEH 2016a).

The Painted Honeyeater is a specialist feeder on mistletoe berries, particularly those of the genus *Amyema* growing on woodland eucalypts and acacias (DSE 2003). It inhabits Boree, Brigalow and Box-Gum Woodlands and Box-Ironbark Forests (OEH 2016b). Within the eastern Pilliga, it is known to utilise riparian woodland and shrub-grass woodland habitats. Other predicted habitat for the species in the study area includes closed forest, water bodies, grassy woodland, heathy woodland and shrubby woodland.

Within the study area, approximately 69,632 ha of habitat has been mapped which provides 69,632 ha of foraging habitat and 69,632 ha of breeding habitat. Within the study region, approximately 308,870 ha of habitat has been mapped which provides 308,870 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27%% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.52% of foraging habitat and 1.52% of breeding habitat in the study area.

Melithreptus gularis gularis (Black-chinned Honeyeater, eastern subspecies) – *Vulnerable*

The Black-chinned Honeyeater (eastern subspecies) occurs predominately west of the Great Dividing Range, extending south from central Queensland, through NSW, Victoria into south eastern South Australia (OEH 2016b) In NSW it is widespread, with records from the tablelands and western slopes of the Great Dividing Range to the north-west and central-west plains, and the Riverina. It is also known from the Richmond and Clarence River areas and from a few scattered sites in the Hunter, Central Coast and Illawarra regions. This species has been recorded within the Pilliga and Pilliga Outwash sub-regions of the Namoi Catchment (OEH 2016b). It is not known to occur in the study area.

The Black-chinned Honeyeater (eastern subspecies) is predominantly associated with box-ironbark woodlands; especially those dominated by *Eucalyptus sideroxylon, E. albens*, *E. microcarpa* and *E. tereticornis* (Forest Red Gum). It also inhabits open forests of smooth-barked gums, stringybarks, ironbarks and tea-trees, and River Red Gum (OEH 2016b). Predicted habitat for the species in the study area includes water bodies, grassy woodland, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland.

Within the study area, approximately 66,805 ha of habitat has been mapped which provides 66,805 ha of foraging habitat and 66,801 ha of breeding habitat. Within the study region, approximately 292,431 ha of habitat has been mapped which provides 292,431 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 861.80 ha of habitat would be directly impacted (861.80 ha of foraging habitat and 861.80 ha of breeding habitat) which equates to 1.29% of foraging and 1.29% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat) which would combine to impact a total of 1.55% of foraging habitat and 1.55% of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Regent Honeyeater, Painted Honeyeater or Black-chinned Honeyeater at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

None of the known breeding sites for Regent Honeyeater are in the study area. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the three assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would directly remove the following amount of breeding and foraging habitat for the three assessed species:

- Regent Honeyeater: 796.80 ha of foraging habitat which constitutes approximately 1.38% of foraging habitat in the study area.

- Painted Honeyeater: 885.00 ha of habitat (885.00 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.27% of foraging habitat and 1.27% of breeding habitat in the study area.
- Black-chinned Honeyeater: 861.80 ha of habitat (861.80 ha of foraging habitat and 861.80 ha of breeding habitat). This constitutes approximately 1.29% of foraging habitat and 1.29% of breeding habitat in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss the following amounts of foraging and breeding habitat for the three assessed species:

- Regent Honeyeater: 157.48 ha of habitat which combines with direct impacts to constitute a total impact of 1.66% of foraging habitat in the study area.
- Painted Honeyeater: 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.52% of foraging habitat and 1.52% of breeding habitat in the study area.
- Black-chinned Honeyeater: 170.71 ha of habitat (170.71 ha of foraging habitat and 170.71 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.55% of foraging habitat and 1.55% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the three assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the three assessed species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the three assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the three assessed species in the study region (the locality).

The habitat to be directly or indirectly impacted provides foraging and breeding habitat (excluding Regent Honeyeater) for the three assessed species. The study area would still maintain over 98% of habitat for the three assessed species which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the three assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program Regent Honeyeater has been assigned as a site-managed species. The study area is not within the four management sites listed for this species and therefore there are no actions relevant to the study area. Painted Honeyeater and Black-chinned Honeyeater have both been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following relevant management actions are applicable for Painted Honeyeater and have been discussed in relation to the project:

1. *Encourage retention of natural densities of mistletoes, particularly Amyema spp.* The location of mistletoe would be recorded during the pre-clearance survey and removal would be avoided or minimised as possible.

2. *Encourage and undertake studies to determine the species status, distribution, habitat and resource requirements.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat. Data collected includes distribution, habitat use and resource use observed. Biodiversity monitoring proposed to be undertaken as part of the project would continue to collect this data.

The following relevant management actions are applicable for Black-chinned Honeyeater and have been discussed in relation to the project:

1. *Conduct ecological research to determine habitat and resource requirements, threats and conservation issues.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat, known and possible threats and actions for long-term conservation of the species in the study area.

Predation by foxes is listed as a threat for the canopy foraging woodland birds (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to these species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the three assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Regent Honeyeater, Painted Honeyeater or Black-chinned Honeyeater. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Regent Honeyeater, Painted Honeyeater or Black-chinned Honeyeater.

Wetland or aquatic birds

Anseranas semipalmata (Magpie Goose), *Botaurus poiciloptilus* (Australasian Bittern), *Ephippiorhynchus asiaticus* (Black-necked Stork), *Grus rubicunda* (Brolga), *Oxyura australis* (Blue-billed Duck), *Rostratula australis* (Australian Painted Snipe) and *Stictonetta naevosa* (Freckled Duck) and are considered in this assessment.

Anseranas semipalmata (Magpie Goose) – Vulnerable

The Magpie Goose is still relatively common in the northern Australian tropics, from Fitzroy River in Western Australia across to Rockhampton in Queensland, but disappeared from south-east Australia by 1920 due to drainage and overgrazing of reed swamps used for breeding. Since the 1980s, however, there have been an increasing number of records in central and northern NSW, and vagrants can even follow food sources to south-eastern NSW (OEH 2016b). This species is known north of the study area, mainly around Narrabri Lake and Wee Waa (OEH 2016a). It has not been recorded in the study area.

The Magpie Goose is mainly found in shallow (less than 1 metre deep) sedge or rush-dominated wetlands; mainly those on floodplains of rivers (Marchant & Higgins 1993; Simpson & Day 2010). The species forages in terrestrial as well as aquatic habitats, including grasslands, pastures, wetlands, well-vegetated dams and crops. It roosts in tall vegetation and nests are formed in trees over deep water or on a floating platform of flattened reeds. Water bodies are the habitat type predicted to be utilised by the Magpie Goose in the study area.

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

Botaurus poiciloptilus (Australasian Bittern) – Endangered

The Australasian Bittern occurs from south-east Queensland to south-east South Australia, Tasmania and the south-west of Western Australia (Marchant & Higgins 1990). They are widespread but uncommon across NSW, found over much of the state except for the far north-west. There is the potential for this species to occur within the study area as they are known to occur in the Pilliga and Pilliga Outwash sub-regions of the Namoi catchment (OEH 2016b). There are records from the 1970s in the Pilliga Nature Reserve and to the north-west of the study area (OEH 2016a; DotE 2014).

The species favours permanent and seasonal freshwater habitats, particularly those dominated by sedges, rushes or reeds (e.g. *Phragmites, Cyperus, Eleocharis, Juncus, Typha, Baumea, Bolboschoenus*) or cutting grass (*Gahnia*) growing on a muddy or peaty substrate (Marchant & Higgins 1990). In inland Australia, this may include freshwater wetlands, tussocky wet paddocks, drains or rice fields((OEH 2016b). Water bodies are the predicted habitat for the species within the study area. The Australasian Bittern forages in still, shallow water up to 0.3 m deep with medium to low vegetation density. Available data indicate that it breeds in relatively deep, densely-vegetated freshwater swamps and pools, building its nests in deep cover over shallow water (Marchant & Higgins 1990).

No foraging habitat in the study area would be directly or indirectly impacted. There is no breeding habitat mapped in the study area.

Ephippiorhynchus asiaticus (Black-necked Stork) – Endangered

In Australia, Black-necked Storks are widespread in coastal and subcoastal northern and eastern Australia, south to central-eastern NSW and with vagrants recorded at scattered sites well away from the coast (for example, near Moree, north-east of Hay and in Victoria). In NSW, the species becomes more uncommon south of the Northern Rivers region, and rarely occurs south of Sydney (OEH 2016b). The species is known to occur within the study area, having been recorded at Yarrie Lake by Central Coast Bird Observers in 2012 (OEH 2016a). It has also been recorded from several sites north of the study area near Narrabri (OEH 2016a).

In NSW, floodplain wetlands (swamps, billabongs, watercourses and dams) of the major coastal rivers are the key habitat or the Black-necked Stork (OEH 2016b). The species is also associated with estuarine and littoral habitats, and occasionally woodland and grassland floodplains (Marchant & Higgins 1993). It forages in water 5 cm – 30 cm deep, mainly in open fresh waters, extensive sheets of shallow water over grasslands or sedgeland, mangroves, mudflats, shallow swamps with short emergent vegetation and permanent billabongs and pools on floodplains (Marchant & Higgins 1993; OEH 2016b). Black-necked Storks build large nests high in tall trees close to water. Water bodies are the predicted habitat for the species within the study area.

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

***Grus rubicunda* (Brolga) – Vulnerable**

The Brolga was formerly found across most of mainland Australia, except for the south-east corner and the south-western third of the country. Whilst it is still abundant in the northern tropics, its distribution is very sparse across the southern part of its range (OEH 2016b). The species has been recorded north of the study area in Jacks Creek State Forest and along the Namoi River (OEH 2016b; DotE 2014). It has not been recorded in the study area.

The Brolga inhabits large open wetlands (including ephemeral and permanent swamps), grassy plains, coastal mudflats and irrigated croplands and, on the coast, mangrove-studded creeks and estuaries. It is less common in arid and semi-arid regions, but will occur close to water in these areas. Brolgas will feed in dry grassland or ploughed paddocks; however, they also depend on access to wetland habitats (OEH 2016b). Nesting comprises a platform of grasses and sticks, augmented with mud, on an island or in the water. Predicted habitat for the Brolga within the study region includes water bodies and grassland.

Within the study area, approximately 9,565 ha of habitat has been mapped which provides 9,565 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 40,739 ha of habitat has been mapped which provides 40,739 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 75.90 ha of foraging habitat would be directly impacted which equates to 0.79% of foraging habitat directly impacted in the study area. No foraging or breeding habitat would be indirectly impacted in the study area.

***Oxyura australis* (Blue-billed Duck) – Vulnerable**

The Blue-billed Duck occurs in both south-eastern and south-western Australia (Blakers et al. 1984; Marchant & Higgins 1990). It is widespread in NSW, but is most concentrated in the southern Murray-Darling Basin area. It is generally only during summer or in drier years that they are seen in coastal areas (OEH 2016b). The species has not been recorded in the study area however it is known to occur north along the Namoi River and east near Gunnedah (OEH 2016b).

The species is completely aquatic, preferring to forage within or beside tall, dense vegetation, and as far from the shore as possible when cover permits (Marchant & Higgins 1990). In winter, flocks congregate on large, open, fresh to saline wetlands on the Murray River system and coastal lakes. During the breeding season, the Blue-billed Duck disperses up to 300 km away to large permanent inland wetlands and swamps, with dense aquatic vegetation and deep water. The species usually nests in *Typha* sp. (Cumbungi) over deep water but will also nest in trampled vegetation in Lignum, sedges or Spike-rushes (OEH 2016b). Water bodies are the predicted habitat for the species within the study area.

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

***Rostratula australis* (Australian Painted Snipe) – Endangered**

The Australian Painted Snipe has been recorded in wetland habitats in all states of Australia. It is most common in eastern Australia, where it has been recorded at scattered locations throughout much of Queensland, NSW, Victoria and south-eastern South Australia. It has been recorded less frequently at a smaller number of more scattered locations farther west in South Australia, the Northern Territory and Western Australia. The species has mainly been recorded breeding in the Murray-Darling region, but has also been recorded in south-east Queensland, eastern NSW, south-east South Australia and the Mt Lofty Ranges (DotE 2016b). Records of this species occur south in the Pilliga Nature Reserve, east in the Liverpool Plains and north near Narrabri and Pilliga (OEH 2016a). There are no records in the study area.

The Australian Painted Snipe is found in shallow terrestrial freshwater wetlands, preferring the fringes of swamps, dams and nearby marshy areas, where there is a cover of grasses, lignum, low scrub or open timber (OEH 2016b). Water bodies are the predicted habitat for the species within the study area. It roosts during the day in dense vegetation, and forages nocturnally on mud-flats and in shallow water, feeding on worms, molluscs, insects and some plant-matter (OEH 2016b). It generally nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds. Most nests recorded have been located on small islands in freshwater wetlands, but nesting may also occur near swamps, and flooded areas of grazing land or other vegetation (Marchant & Higgins 1993).

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

***Stictonetta naevosa* (Freckled Duck) – Vulnerable**

The Freckled Duck is found primarily in south-eastern and south-western Australia, and inland along the Diamantina River and Cooper Creek, occurring as a vagrant elsewhere. It breeds in large temporary swamps created by floods in the Bulloo and Lake Eyre basins and the Murray-Darling system, particularly along the Paroo and Lachlan Rivers, and other rivers within the Riverina (OEH 2016b). This species has been recorded along the Namoi River and east near Gunnedah. It has not been recorded in the study area.

In inland Australia, this species prefers permanent freshwater swamps and creeks with heavy growth of *Typha* sp. and Lignum (Frith 1965; 1982). During drier times they move from ephemeral breeding swamps to more permanent waters such as lakes, reservoirs, farm dams and sewage ponds (OEH 2016b). They generally rest in dense cover during the day in deep water. Nests are usually located in dense vegetation at or near water level (OEH 2016b). Water bodies are the predicted habitat for the species within the study area.

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

1. In the case of a threatened species, whether the action proposed is likely to have

an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Magpie Goose, Australasian Bittern, Black-necked Stork, Brolga, Blue-billed Duck, Australian Painted Snipe or Freckled Duck at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

No breeding habitat for Australasian Bittern or Brolga occurs in the study area. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of each species lifecycle or which reduce habitat quality. In order to place the populations of the seven assessed species at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, fledging and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoiding aquatic habitat, staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting habitat for the majority of species in the study area (excluding Brolga – 0.79% of foraging habitat). Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would not directly remove habitat for Magpie Goose, Australasian Bittern, Black-necked Stork, Blue-billed Duck, Australian Painted Snipe or Freckled Duck. The project would remove up to 75.90 ha of foraging habitat but no breeding habitat for Brolga. This constitutes approximately 0.79% of Brolga foraging habitat removed in the study area.

No foraging or breeding habitat for the seven assessed species would be indirectly impacted.

II. As no aquatic habitat would be removed or indirectly impacted, no fragmentation of these habitats would occur.

III. The habitat to be directly impacted provides foraging habitat for Brolga but is not considered important for the long-term survival of the species. The study area would still maintain over 99% of foraging habitat for Brolga in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the avoidance of aquatic habitat and staged construction, the magnitude and duration of the direct impacts on habitat is not likely to impact the long-term survival of the seven assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program Brolga has been assigned as a partnership species. Magpie Goose, Australasian Bittern, Black-necked Stork, Blue-billed Duck, Australian Painted Snipe and Freckled Duck have all been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following relevant management actions are applicable for Magpie Goose and have been discussed in relation to the project:

1. *Restore natural hydrological regimes to freshwater wetlands, and maintain existing hydrological regimes. Do not fill or drain wetlands. Retain and protect native vegetation in and around wetlands, and restore degraded wetlands.* Waterbodies in the study area have been identified and mapped. They would not be directly or indirectly impacted.

2. *Improve the protection of Magpie Goose habitat by excluding stock, reducing grazing pressure and controlling weeds in wetlands. Avoid placing powerlines over or near wetlands/ nest sites.* Weed control in the study area would be managed by the implementation of the pest and weed management plan. No infrastructure would be placed over or near wetland habitat proposed for the project.

3. *Reduce nutrient runoff into wetlands, and avoid the use of herbicides and pesticides near or in wetlands.* Indirect impacts would be controlled to ensure no indirect impact on wetland habitat. No herbicides or pesticides would be used near or in wetlands.

4. *Promote and support weed control programs within wetlands.* Weed control in the study area would be managed by the implementation of the pest and weed management plan proposed for the project.

5. *Retain native vegetation with wetlands.* Wetland vegetation would not be directly or indirectly impacted in the study area.

None of the management actions for Australasian Bittern are relevant to the project.

The following relevant management actions are applicable for Black-necked Stork and have been discussed in relation to the project:

1. *Collect baseline data on the abundance of this species and monitor long-term changes in population density.* Records in the study area would be supplied to OEH under the OEH licence agreement and could be used to support a long-term trends analysis of the species.

2. *Support research into the ecology of Black-necked Storks in NSW. Encourage and support research on movements, habitat use and current threats to Black-necked Storks. Develop strategies to mitigate threats.* If Black-necked Storks are located in the study area, the biodiversity monitoring proposed to be undertaken as part of the project would be designed to obtain information on distribution, habitat use and signs of threats in the study area. The mitigation measures would be assessed to ensure that impacts are appropriately avoided, minimised or impacted.

3. *Improve the protection of Black-necked Stork habitat by excluding stock, reducing grazing pressure and controlling weeds in wetlands. Avoid placing powerlines over or near wetlands/ nest sites.* Weed control in the study area would be managed by the implementation of the pest and weed management plan. No infrastructure would be placed over or near wetland habitat.

4. *Reduce nutrient runoff into wetlands known to be used by Black-necked Stork, and avoid the use of herbicides and pesticides near or in wetlands.* Indirect impacts would be controlled to ensure no indirect impact on wetland habitat. No herbicides or pesticides would be used near or in wetlands.

The following relevant management actions are applicable for Brolga and have been discussed in relation to the project:

1. *Retain or reintroduce water flows to wetlands, soaks, swamps etc.* Water flow would

be managed when designing and locating infrastructure. This would include assessing where water would flow and pool in the landscape to ensure that flows into wet areas are not impeded by infrastructure placement.

The following relevant management actions are applicable for Blue-billed Duck and have been discussed in relation to the project:

1. *Control foxes.* The feral animal control strategy proposed as part of the project would control foxes in areas of potential habitat in the study area.

The following relevant management actions are applicable for Australian Painted Snipe and have been discussed in relation to the project:

1. *Assess the species' status via review of past surveys and the literature, and by conducting and encouraging surveys in known and potential habitat in appropriate seasons.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of habitat. The literature review did not identify known habitat in the study area but potential habitat has been identified and mapped.

The following relevant management actions are applicable for Freckled Duck and have been discussed in relation to the project:

1. *Control feral predators in known and potential habitat of the species.* The feral animal control strategy proposed as part of the project would control predators including feral foxes, cats and dogs in areas of potential habitat in the study area.

2. *Control feral pigs and goats in order to reduce habitat destruction in potential and known habitat of the species.* The feral animal control strategy proposed as part of the project would control feral pigs and goats in areas of potential habitat in the study area.

Predation by foxes is listed as a threat for the wetland and aquatic birds (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to these species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or

is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the seven assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for these species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Magpie Goose, Australasian Bittern, Black-necked Stork, Brolga, Blue-billed Duck, Australian Painted Snipe or Freckled Duck. The direct impact of less than 1% of the Brolga foraging habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Magpie Goose, Australasian Bittern, Black-necked Stork, Brolga, Blue-billed Duck, Australian Painted Snipe or Freckled Duck.

1.5 Mammals

Aepyprymnus rufescens (Rufous Bettong) – Vulnerable

The Rufous Bettong has a patchy distribution from Cooktown, Queensland, to north-eastern NSW as far south as Mt Royal National Park. In NSW, it has largely disappeared from inland areas, although there are sporadic, unconfirmed records from the Pilliga and Torrington districts (OEH 2016b). The species has not been recorded in the study area.

The species prefers forests with a grassy to sparse understorey, from tall wet sclerophyll forests on the coast to the dry forests and open woodlands west of the Great Dividing Range. In the day they shelter in a grassy nest constructed in a shallow depression at the base of a tussock or fallen log (Dennis & Johnson 2008). Predicted habitat for the species within the study area includes grassland, grassy woodland, shrub-grass woodland and shrubby woodland.

Within the study area, approximately 45,563 ha of habitat has been mapped which provides 45,563 ha of foraging habitat and 36,098 ha of breeding habitat. Within the study region, approximately 245,413 ha of habitat has been mapped which provides 245,413 ha of foraging habitat and 211,106 ha of breeding habitat. An upper limit of 498.70 ha of habitat would be directly impacted (498.70 ha of foraging habitat and 422.80 ha of breeding habitat) which equates to 1.09% of foraging and 1.17% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 83.25 ha of habitat (83.25 ha of foraging habitat and 83.25 ha of breeding habitat) which would combine to impact a total of 1.28% of foraging habitat and 1.40% of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Rufous Bettong at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Rufous Bettong lifecycle or which reduce habitat quality. In order to place the populations of Rufous Bettong at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and nesting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to

have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 498.70 ha of Rufous Bettong habitat, which provides 498.70 ha of foraging habitat and 422.80 ha of breeding habitat. This constitutes approximately 1.09% of foraging habitat and 1.17% of breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 83.25 ha of habitat for Rufous Bettong which provides 83.25 ha of foraging habitat and 83.25 ha of breeding habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.28% of foraging habitat and 1.40% breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the Rufous Bettong would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the Rufous Bettong. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Rufous Bettong would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the Rufous Bettong in the study region (the locality).

Rufous Bettong have not been recorded in the study area but could potentially use the study area for foraging and breeding. The study area would still maintain over 98% of habitat for the Rufous Bettong which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Rufous Bettong in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the Rufous Bettong in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Rufous Bettong has been assigned a landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable and have been discussed in relation to the project:

5. *Consider landscape-scale connectivity of habitat in planning*. Rufous Bettong records within connected habitat have been considered in this assessment. Habitat fragmentation and connectivity in the landscape has been considered in the study area in this assessment. Planning of infrastructure using the ecological scouting framework would ensure that habitat is not isolated and that movement through the landscape would not be impeded.

6. *Conduct surveys for rufous bettongs in the west of its range. Continue to survey for the species in areas already subject to surveys.* Surveys for this ecological assessment were undertaken in the west of the Rufous Bettong range. This included installing remote cameras and hair funnels at a previous record south-west of the study area to indicate Rufous Bettong activity in the broader connected habitat.

7. *Control feral herbivores in potential habitat for this species.* The feral animal control strategy proposed as part of the project would control feral herbivores in the study area. Potential foraging and breeding habitat has been identified and mapped in the study area which would be available to target control effort.

Predation by foxes is a threat for Rufous Bettong (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the Rufous Bettong:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Rufous Bettong. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Rufous Bettong.

Dasyurus maculatus (Spotted-tailed Quoll) – Vulnerable

The range of the Spotted-tailed Quoll has contracted considerably since European settlement. It now has a disjunct distribution along the east coast of Australia, extending from south-eastern Queensland through NSW and Victoria to Tasmania (OEH 2016b). The species was not observed during field surveys and there are no existing records for the species within the study area. Previous records of the Spotted-tailed Quoll in the Pilliga are sparse, with a record in the Pilliga Nature Reserve from 2006 and three records adjacent to the Pilliga forests (OEH 2016a). One record is from the Warrumbungles from 2008 and two records are south-east of the Pilliga forests from 1994 and 2004. While the species occurs more frequently in coastal areas, there are scattered records for Spotted-tailed Quolls west of the study area along the Barwon River.

The Spotted-tailed Quoll inhabits a range of environments including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline (DotE 2016b). The Spotted-tailed Quoll uses a range of habitat within its large home range (up to 750 ha for females and up to 3,500 ha for males; OEH 2014b). Important habitat features include densely-vegetated creek lines for movement; hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky cliff-faces for den sites; and flat rocks among boulder fields and rocky cliff-faces for latrine sites. The species requires habitat that supports a wide range of prey including gliders, possums, small wallabies, rats, birds, bandicoots, rabbits and insects (OEH 2016b). Within the study area, all habitat types are considered predicted habitat for the species.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.45% of foraging habitat and 1.53% of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have

an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Spotted-tailed Quoll at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Spotted-tailed Quoll lifecycle or which reduce habitat quality. In order to place the populations of Spotted-tailed Quoll at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and nesting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoidance and minimisation of removal of hollow-bearing trees and other important habitat features, staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would remove up to 988.80 ha of Spotted-tailed Quoll habitat, which provides 988.80 ha of foraging habitat and 885.00 ha of breeding habitat. This constitutes approximately 1.23% of foraging habitat and 1.27% of breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 181.11 ha of habitat for Spotted-tailed Quoll which provides 181.11 ha of foraging habitat and 175.41 ha of breeding habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.45% of foraging habitat and 1.53%breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the Spotted-tailed Quoll would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the Spotted-tailed Quoll. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Spotted-tailed Quoll would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the Spotted-tailed Quoll in the study region (the locality).

Spotted-tailed Quoll have not been recorded in the study area but it could potentially use the study area for foraging and breeding. The study area would still maintain over 98% of habitat for the Spotted-tailed Quoll which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Spotted-tailed Quoll in the study region.

5.	***Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).***

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the Spotted-tailed Quoll in the study area.

6.	***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

Under the Saving our Species program, Spotted-tailed Quoll has been assigned a landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable and have been discussed in relation to the project:

1. *Conduct field and community surveys for the Spotted-tailed Quoll in areas where its distribution is poorly known. Areas identified for large-scale urban development (i.e. Far north coast, Hunter) and coastal reserves should be the highest priority.* The distribution of the Spotted-tailed Quoll in the Pilliga Forests is not well known. Extensive remote camera, hair tube and spotlighting field surveys were undertaken for this ecological assessment in the study area, however no individuals were observed.

2. *Based on research, develop and implement a protocol for use of poison baits that further reduces impacts on individual Spotted-tailed Quolls.* Baiting programs that would be implemented by the feral animal control strategy proposed as part of the project would be undertaken following the most up to date methods to ensure impacts on Spotted-tailed Quolls are considered and minimised.

Predation by foxes is listed as a threat for Spotted-tailed Quoll (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the Spotted-tailed Quoll:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses

  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Spotted-tailed Quoll. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Spotted-tailed Quoll.

Macropus dorsalis (Black-striped Wallaby) – Endangered

The Black-striped Wallaby occurs from the Townsville area in Queensland to northern NSW, where it occurs on both sides of the Great Dividing Range. On the North West Slopes of NSW, it is found to south of Narrabri (OEH 2016b). At least 17 Black-striped Wallabies were recorded at 15 sites throughout the study area. Records in the study area extend right down to the south of the study area.

Previously, Black-striped Wallabies were known to occur in the study area, but records were largely from the north of the study area, in closed forest and grassland habitat in Brigalow State Conservation Area, Brigalow Nature Reserve and adjacent to roadsides. The locations of these records are influenced by the survey locations for targeted Black-striped Wallaby surveys in the reserve areas. The scattered records west of the study area are from the 1970s and 1980s and specific habitat types cannot be obtained due to the lack of accuracy in these records (OEH 2016a).

Preferred habitat for the Black-striped Wallaby is forested country characterised by a dense shrub layer (Dennis & Johnson 2008). This dense vegetation, used for diurnal shelter, must occur near a more open, grassy area to provide suitable habitat for foraging, which occurs between dusk and dawn (OEH 2016b) Prior to this survey, habitat preferences on the North West Slopes were thought to mainly consist of dense vegetation, including brigalow, ooline and semi-evergreen vine thicket vegetation. It was also known to occasionally use bulloke, ironbark and other dense regrowth (OEH 2016b). In this survey, the Black-striped Wallaby has been recorded utilising riparian woodland, heathy woodland, closed forest and shrub grass woodland throughout the forested and cleared portions of the study area. In the study area, the species is predicted to also utilise all other habitat types within the study area.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 80,498 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 357,191 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 988.80 ha of breeding habitat) which equates to 1.23% of foraging and 1.23% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 181.11 ha of breeding habitat) which would combine to impact a total of 1.45% of both foraging and breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Black-striped Wallaby at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Black-striped Wallaby lifecycle or which reduce habitat quality. In order to place the populations of Black-striped Wallaby at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and refuge. Growth requires adequate habitat and conditions for refuge, foraging and communication. Development requires adequate habitat and conditions for refuge, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions for foraging and refuge. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2.	***In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would remove up to 988.80 ha of Black-striped Wallaby habitat, which provides 988.80 ha of foraging habitat and 988.80 ha of breeding habitat. This constitutes approximately 1.23% of foraging habitat and 1.23% of breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 181.11 ha of habitat for Black-striped Wallaby which provides 181.11 ha of foraging habitat and 181.11 ha of breeding habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.45% of foraging habitat and 1.45% breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the Black-striped Wallaby would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the Black-striped Wallaby. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Black-striped Wallaby would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the Black-striped Wallaby in the study region (the locality).

Black-striped Wallaby have been recorded in the study area in both forested and open habitat with records distributed throughout the study area. The habitat in the study area is considered to be important habitat for Black-striped Wallaby foraging and breeding. However, the study area would still maintain over 98% of important habitat for the Black-striped Wallaby which would continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Black-striped Wallaby in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for Black-striped Wallaby in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Black-striped Wallaby has been assigned a site-managed species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

Three management sites have been established for Black-striped Wallaby where conservation activities need to take place to ensure the conservation of this species; Koreelah Range, Richmond Range and Brigalow. The study area is located within the Brigalow site which extends over 33,695 ha from Boggabri in the east to Pilliga (the town) in the west and from Bellata in the north to Baradine in the south

The following management actions are applicable and have been discussed in relation to the project:

1. *Rural/residential/industrial development: ensure land management is sympathetic to the long term requirements of the species.* The project would impact on less than 98% of the Black-striped Wallaby habitat in the study area. The biodiversity monitoring proposed to be undertaken as part of the project would collect data on the long-term status of the species in the study area and would coordinate additional efforts required to ensure the population remained viable.

2. *Track species abundance/condition over time.* Prior to surveys for this assessment, records for Black-striped Wallaby were largely outside of the Pilliga forests. The field surveys have recorded Black-striped Wallaby throughout the study area. The

biodiversity monitoring proposed to be undertaken as part of the project would collect data on the long-term status of the species in the study area including data on abundance, distribution and signs of stress observed.

Predation by foxes is listed as a threat for Black-striped Wallaby (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the Black-striped Wallaby:

- Invasive species
    - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
    - Competition and habitat degradation by feral goats (*Capra hircus*)
    - Invasion of native plant communities by exotic perennial grasses
    - Predation by the European Red Fox (*Vulpes vulpes*)
    - Predation by the feral cat (*Felis catus*)
    - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
    - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
    - Clearing of native vegetation
    - Removal of dead wood and dead trees.
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Black-striped Wallaby. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Black-striped Wallaby.

Pseudomys pilligaensis (Pilliga Mouse) – Vulnerable

It is important to note that the Pilliga Mouse is now considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed & Ford 2007; Ford 2008), as cited in DoE 2014). Importantly, this taxonomic change has not yet been formally recognised under the EPBC Act (DotE 2016b); hence this assessment considers the Pilliga Mouse as currently listed.

The Pilliga Mouse is restricted to the Pilliga region of NSW, with the greatest density of records for the species occurring within the Pilliga Forest (OEH 2016b). The few records from outside the Pilliga include Binnaway Nature Reserve (approximately 30 km south-east of Coonabarabran) and Bebo State Forest (approximately 230 km north-east of Narrabri) (OEH 2016a; NPWS 2002b; Jarman & Green 2000). Its distribution is sparse and it is thought to undergo temporal fluctuations. The reasons for the irruptive population phases are unknown but may relate to recent fire history and high rainfall periods (Tokushima et al. 2008). This species has been recorded in the study area throughout the forested portion.

It is thought that primary habitat patches support this species playing an important role as refuge habitat during times of population contraction. A wider range of secondary habitat is used during a population irruption when environmental conditions are favourable (Tokushima et al. 2008). Primary habitat includes heathy woodland on sandy soils suitable for burrowing with a low and diverse shrubby layer and a diverse ground layer. Secondary habitat included shrubby and heathy woodland but with generally lower shrub diversity or cover. Consistent habitat features of most areas in which the Pilliga mouse has been recorded include high plant species richness, a moderate to high density of low shrubs, and a moist groundcover of plants, litter and fungi (Fox & Briscoe 1980; OEH 2016b; Tokushima et al. 2008). In the study area, the species is known to utilise heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitats, and is predicted to also use grassy woodland habitats.

The population size of the Pilliga Mouse is hard to estimate, especially as demographics are irruptive. The population has been estimated to be approximately 50,000 to 100,000 during irruptive periods (Paull & Milledge 2011). Peak density has been calculated at 15-90 Pilliga Mice / ha in comparison to low density calculated at 0-5 Pilliga Mice / ha (Tokushima et al. 2008; DotE 2016b).

Within the study area, 8,595 ha of primary habitat and 14,609 ha of secondary habitat has been mapped. Both these habitat categories have potential to support breeding and foraging and in particular primary habitat supports Pilliga Mouse during population bust periods. There are 68,050 ha of habitat in the study area identified as dispersal habitat. The dispersal habitat comprises all primary and secondary habitat as well as additional habitat that could support Pilliga Mouse during boom periods. An upper limit of 889.31 ha of habitat would be directly impacted (135.40 ha of primary habitat, 181.51 ha of secondary habitat and 572.76 ha of dispersal habitat) which equates to 1.57% of primary habitat, 1.24% of secondary habitat and 0.84% of dispersal habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 162.87 ha of habitat (24.73 ha of primary habitat, 33.24 ha of secondary habitat and 104.9 ha of dispersal habitat) which would combine to impact a total of 1.86% primary habitat, 1.47% secondary habitat and 1.00% of dispersal habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Pilliga Mouse at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Pilliga Mouse lifecycle or which reduce habitat quality. In order to place the populations of Pilliga Mouse at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and burrowing. Growth requires adequate habitat and conditions for burrowing, foraging and communication. Development requires adequate habitat and conditions for burrowing, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and burrowing. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2.	***In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would remove up to 889.31 ha of Pilliga Mouse habitat, which provides 135.04 ha of primary habitat, 181.51 ha of secondary habitat and 572.76 ha of dispersal habitat. This constitutes approximately 1.57% of primary habitat, 1.24% of secondary habitat and 0.84% of dispersal habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 162.87 ha of habitat for Pilliga Mouse which provides 24.73 ha of primary habitat, 33.24 ha of secondary habitat and 104.9 ha of dispersal habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.86% primary habitat, 1.47% secondary habitat and 1.00% of dispersal habitat in the study area.

II. Additional fragmentation of primary, secondary and dispersal habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

During boom periods, the Pilliga Mouse is thought to be able to move across existing open spaces in the study area. Hence, during these times, the fragmentation associated with the project is not considered wide enough to inhibit dispersal. However, during bust periods when the Pilliga Mouse population is congregated within primary and secondary habitats, there is potential for the fragmentation of primary and secondary habitat patches to restrict movement. This may restrict current overlapping of home ranges, inhibiting breeding potential between individuals on either side of the corridor. The habitat present on either side of the linear corridors is extensive and would support Pilliga Mouse foraging and breeding.

The 30 m wide corridor would increase the intersection of three patches of primary habitat. These patches are currently separated by up to 10 m from the existing clearing. The smallest patch of primary habitat that would be separated by 30 m would be 5 ha. This patch of primary habitat would remain linked to a larger patch of primary habitat (57 ha) by 32 ha of secondary habitat. The remaining patches of primary habitat would be in patches of between 20 ha and 168 ha. All of the patches of primary habitat are connected to patches of secondary habitat with the mosaic of primary and secondary patches being completely connected on either side of the corridor.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Pilliga Mouse would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides primary, secondary and dispersal habitat, it is not considered necessary for the long-term survival of the Pilliga Mouse in the study region (the locality).

The primary habitat and secondary habitat is important habitat for Pilliga Mouse. This habitat supports the population during bust periods and allows the population to persist during unfavourable environmental conditions. The study area would still maintain over 98% of primary and secondary habitat for the Pilliga Mouse which could continue to support foraging and breeding in the study area. Over 98% of dispersal habitat in the study area would be maintained which would allow dispersal during boom periods. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Pilliga Mouse in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for Pilliga Mouse in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Pilliga Mouse has been assigned a landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable and have been discussed in relation to the project:

5. *Control foxes, cats and pigs in the Pilliga.* The feral animal control strategy proposed as part of the project would manage and monitor cats and pigs in the study area.

6. *Provide map of known occurrences to Pilliga East and Etoo State Forests and Rural Fire Service and seek inclusion of mitigative measures on Bush Fire Risk Management Plan(s), risk register and/or operation map(s).* All records of the Pilliga Mouse have been and would continue to be supplied to OEH under the OEH licence agreement. These records would then be available to use as part of this management action.

7. *Develop and implement a monitoring program that identifies population and ecological trend in response to threats (predators, fire, drought etc.).* The biodiversity monitoring proposed to be undertaken as part of the project would aim to identify responses to direct and indirect threats posed by the project.

Predation by foxes is listed as a threat for Pilliga Mouse (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the Pilliga Mouse:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)

  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Pilliga Mouse. The direct and indirect impact of less than 2% of the primary and secondary habitat in the study area and less than 2% of the dispersal habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Pilliga Mouse.

Phascolarctos cinereus (Koala) – Vulnerable

The Koala has a fragmented distribution throughout eastern Australia from north-east Queensland to the Eyre Peninsula in South Australia. In NSW, it mainly occurs on the central and north coasts with some populations occurring west of the Great Dividing Range. Koalas are also known from several sites on the southern tablelands (OEH 2016b).

Koalas have been previously recorded throughout the Pilliga and surrounding areas. A large population is known to occur in the Liverpool Plains near Gunnedah and records continue through to the west of the Pilliga. Koalas have been recorded in the central and western regions of the Pilliga, and differing reports indicate uncommon to common presence in the east (Kavanagh & Barrott 2001). There are historic records of Koala in the study area, mostly centred in forested habitat west of the Newell Highway. The most recent record is from 2004.

The distribution and population size of Koalas in the Pilliga has varied, with population size believed to have dropped sharply between 1930 and 1980 due to hunting, predation by the European Red Fox, widespread ringbarking of eucalypts, and wildfire. Koala numbers were thought to have increased since the 1980s (Kavanagh & Barrott 2001) following the termination of hunting and ringbarking. However, drought and recent major wildfires (100,000 ha burnt in 2007 in the eastern Pilliga and 100,000 ha burnt in Warrumbungles in 2013) have impacted large areas of potential Koala habitat. Recent surveys for Koala in the Pilliga have found very low numbers in areas previously known to support resident populations (Niche Environment and Heritage 2014). All Koalas were located along Baradine Creek and Etoo Creek and their tributaries, west and southwest of the study area.

Koalas are associated with both wet and dry Eucalypt forest and woodland with a canopy cover of approximately 10 – 70% (Reed et al. 1990), that contains acceptable eucalypt food trees. *Eucalyptus camaldulensis*, a primary Koala food tree species as defined in the Approved Koala recovery plan (DECC 2008) and listed under the State Environmental Planning Policy 44, occurs in the study area. Secondary food trees recorded in the study area include *E. albens*, *E. blakelyi, E. chloroclada, E. conica*, *E. dealbata* (Tumbledown Gum), *E. dwyeri* (Dwyer's red gum), *E. macrocarpa*, *E. melliodora*, *E. pilligaensis* and *E. populnea*. *Eucalyptus macrorhyncha* (Red Stringybark), a listed supplementary food tree, is also present within the study area. *Callitris glaucophylla* is common, and is listed as a tree species used for daytime shelter.

Within the study area, approximately 80,398 ha of potential habitat has been mapped which provides 32,996 ha of foraging and breeding habitat and 80,398 ha of dispersal habitat. Within the study region, approximately 331,510 ha of habitat has been mapped which provides 100,081 ha of foraging and breeding habitat and 331,510 ha of dispersal habitat. An upper limit of 988.80 ha of potential habitat would be directly impacted (449.80 ha of foraging/breeding habitat and 988.80 ha of dispersal habitat) which equates to 1.36% of foraging/breeding habitat and 1.23% of dispersal habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (89.36 ha of foraging/breeding habitat and 181.11 ha of dispersal habitat) which would combine to impact a total of 1.63% of foraging/breeding habitat and 1.46% of dispersal habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Koala at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Koala lifecycle or which reduce habitat quality. In order to place the populations of Koala at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and refuge. Growth requires adequate habitat and conditions for refuge, foraging and communication. Development requires adequate habitat and conditions for refuge, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions for foraging and refuge. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 988.80 ha of potential Koala habitat, which provides 449.80 ha of foraging habitat, 449.80 ha of breeding habitat and 988.80 ha of dispersal habitat. This constitutes approximately 1.36% of foraging habitat, 1.36% of breeding habitat and 1.23%of dispersal habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 181.11 ha of potential habitat for Koala which provides 89.36 ha of foraging habitat, 89.36 ha of breeding habitat and 181.11 ha of dispersal habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.63% of foraging habitat, 1.63% of breeding habitat and 1.46% of dispersal habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the Koala would have the mobility to move between patches. However, habitat not connected by canopy would increase the risk of indirect impacts (such as collision and predation). The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the Koala but would force individuals to move along the ground in between habitat patches. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Koala would be possible around the infrastructure.

III. Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide core Koala habitat. During times of low population numbers, the Koala population is known to persist in areas outside of the study area along Etoo Creek and Baradine Creek. The habitat in the study area is considered to provide potential foraging, breeding and dispersal habitat for Koala during preferable environmental conditions when population numbers are higher than the current status.

Whilst the habitat to be directly or indirectly impacted provides potential foraging and breeding habitat for the Koala, it is not considered important for the long-term survival of the Koala in the study region (the locality). The study area would still maintain over 98% of potential habitat for the Koala. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Koala in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for Koala in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

An approved recovery plan has been prepared for Koala (DECC 2008). The following objectives are applicable and have been discussed in relation to the project:

1. *To conserve koalas in their existing habitat.* In the study area, spotlighting, call playback and habitat assessments have been undertaken and Koala habitat has been identified, categorised and mapped. Additionally, a regional Koala survey in the Pilliga Forests has been undertaken. The study area is not considered to support the koala population in the Pilliga during a population contraction. However, primary habitat in the study area around Yarrie Lake would not be directly or indirectly impacted. Infrastructure would also be avoided or minimised in riparian corridors, which support secondary habitat.

2. *To rehabilitate and restore Koala habitat and populations.* Approximately 98% of Koala habitat in the study area would not be directly or indirectly impacted. Feed and shelter trees in these areas would be able to mature and provide habitat over the duration of the project.

Predation by foxes is listed as a threat for Koala (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the Koala:

- Invasive species
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
- Direct impact
  - Clearing of native vegetation
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Koala in the study area. Over 98% of the potential foraging, breeding and dispersal habitat in the study area would not be directly or indirectly impacted. The loss of less than 2% of potential habitat in the study area is unlikely to cause a viable population to become extinct in the short or long term due to the small percentage of potential habitat that would be impacted.

There are no recent sightings of Koala in the study area and the study area is unlikely to have historically supported a large population of Koala. The study area is unlikely to support an important population of Koala and does not provide key breeding habitat.

Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide important Koala habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

The project is not considered likely to interfere substantially with the recovery of the Koala, as the project is unlikely to result in increased koala fatalities due to dog attack or vehicle strike, is unlikely to result in the spread of disease or pathogens, is unlikely to create a barrier to movement to, between or within habitat critical to the survival of the Koala and is unlikely to change the hydrology of the study area.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Koala.

***Sminthopsis macroura* (Stripe-faced Dunnart) – Vulnerable**

The Stripe-faced Dunnart is distributed throughout much of inland central and northern Australia, extending into central and northern NSW, western Queensland, Northern Territory, South Australia and Western Australia. The species is rare on the NSW Central West Slopes and North West Slopes; in recent times the most easterly records have been located around Dubbo, Coonabarabran, Warialda and Ashford (OEH 2016b). The species has not been recorded within the study area. There is one record of the species from 1980 located approximately 8 kilometres to the north-west of the study area (OEH 2016a).

The species mainly occupies native dry grasslands and low dry shrublands, often along drainage lines (OEH 2016b) but is also found in a variety of other habitats including spinifex grasslands, open salt lakes and low, shrubby, rocky ridges (Morton & Dickman 2008). During the day, it shelters in cracks in the soil, in grass tussocks or under rocks and logs (OEH 2016b). It is almost certainly independent of drinking water (Morton & Dickman 2008). Predicted habitat for the species within the study area includes closed forest, grassland, grassy woodland, heath, heathy woodland, riparian woodland and shrubby woodland.

Within the study area, approximately 44,331 ha of habitat has been mapped which provides 44,331 ha of foraging habitat and 44,331 ha of breeding habitat. Within the study region, approximately 138,750 ha of habitat has been mapped which provides 138,750 ha of foraging habitat and 138,750 ha of breeding habitat. An upper limit of 565.80 ha of habitat would be directly impacted (565.80 ha of foraging habitat and 565.80 ha of breeding habitat) which equates to 1.28% of both foraging and breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 97.76 ha of habitat (97.76 ha of foraging habitat and 97.76 ha of breeding habitat) which would combine to impact a total of 1.50% of both foraging and breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Stripe-faced Dunnart at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Stripe-faced Dunnart lifecycle or which reduce habitat quality. In order to place the populations of Stripe-faced Dunnart at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and nesting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would remove up to 565.80 ha of Stripe-faced Dunnart habitat, which provides 565.80 ha of foraging habitat and 565.80 ha of breeding habitat. This constitutes approximately 1.28% of foraging habitat and 1.28% of breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 97.76 ha of habitat for Stripe-faced Dunnart which provides 97.76 ha of foraging habitat and 97.76 ha of breeding habitat. The direct and indirect impact on habitat would constitute a total impact of approximately 1.50% of foraging habitat and 1.50% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

It is considered that the Stripe-faced Dunnart could move across open spaces but that they would be less likely to due to the decrease in protection from low shrubs. This may restrict current overlapping of home ranges, inhibiting breeding potential between individuals on either side of the corridors, especially along the linear clearing from the Bibblewindi to Leewood infrastructure corridor. The habitat present on either side of the corridor is extensive and would support Stripe-faced Dunnart foraging and breeding.

The 30 m wide corridor would increase the intersection of five patches of foraging and breeding habitat. These patches are currently separated by up to 10 m from the existing clearing. The smallest patch of habitat that would be separated by 30 m would be 2 ha. This patch of habitat is approximately 200 m distance from the next available habitat patch, with native vegetation connecting the two patches. The remaining patches of foraging and breeding habitat would be in patches from 35 ha to over 500 ha.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Stripe-faced Dunnart would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered important for the long-term survival of the Stripe-faced Dunnart in the study region (the locality).

Stripe-faced Dunnart have not been recorded in the study area but it could potentially use the study area for foraging and breeding. The study area would still maintain over 98% of habitat for the Stripe-faced Dunnart which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Stripe-faced Dunnart in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for Stripe-faced Dunnart in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Stripe-faced Dunnart has been assigned a landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable and have been discussed in relation to the project:

1. *Control foxes in vicinity of known populations. Concurrently control or monitor feral cat numbers in case of a resulting increase.* The feral animal control strategy proposed as part of the project would manage and monitor feral cats and foxes.

2. *Control feral goats, pigs and rabbits near known populations (best practice: locally efficient and effective).* The feral animal control strategy proposed as part of the project would manage and monitor goats, pigs and rabbits.

3. *Assess the species' status via a review of the literature and past surveys, and by conducting and encouraging surveys in known and potential habitat.* This ecological assessment has involved a literature review of previous research and extensive field surveys to identify areas of foraging and breeding habitat in the study area.

Predation by foxes is listed as a threat for Stripe-faced Dunnart (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant to this species. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to the Stripe-faced Dunnart:

- Invasive species
    - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
    - Competition and habitat degradation by feral goats (*Capra hircus*)
    - Invasion of native plant communities by exotic perennial grasses
    - Predation by the European Red Fox (*Vulpes vulpes*)
    - Predation by the feral cat (*Felis catus*)
    - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
    - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
    - Clearing of native vegetation
    - Removal of dead wood and dead trees.
- Environmental modification
    - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for this species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Stripe-faced Dunnart. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Stripe-faced Dunnart.

Arboreal hollow-dependent mammals

Cercartetus nanus (Eastern Pygmy-possum) and *Petaurus norfolcensis* (Squirrel Glider) are considered in this assessment.

***Cercartetus nanus* (Eastern Pygmy-possum) – Vulnerable**

The Eastern Pygmy-possum is found in south-eastern Australia, from southern Queensland to eastern South Australia and in Tasmania. In NSW it extends from the coast inland as far as the Pilliga, Dubbo, Parkes and Wagga Wagga on the western slopes (OEH 2016b). The species was detected adjacent to the eastern boundary of the study area in the Pilliga East and Jacks Creek State Forests. There are also multiple previous records from the southern half of the study area within the Pilliga East State Forest (OEH 2016a).

The species is found in wet and dry eucalypt forest, subalpine woodland, coastal banksia woodland and wet heath (Menkhorst & Knight 2004). In general woodlands and heath are its preferred habitat (OEH 2016b). Small tree hollows are favoured for nesting during the day, but nests have also been found under bark, in rotten stumps, holes in the ground, old bird nests, Ringtail Possum drays, thickets of vegetation and in the branch forks of tea-trees (Turner & Ward 1995; OEH 2016b). In the eastern Pilliga, Pygmy-possums are known to utilise heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. The species is also predicted to utilise grassy woodland habitats in the study area.

Within the study area, approximately 56,666 ha of habitat has been mapped which provides 56,666 ha of foraging habitat and 56,666 ha of breeding habitat. Within the study region, approximately 228,598 ha of habitat has been mapped which provides 228,598 ha of foraging habitat and 228,598 ha of breeding habitat. An upper limit of 774.80 ha of foraging and breeding habitat would be directly impacted which equates to 1.37% of both foraging and breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 153.01 ha of foraging and breeding habitat which would combine to impact a total of 1.64% of both foraging and breeding habitat in the study area.

***Petaurus norfolcensis* (Squirrel Glider) – Vulnerable**

The squirrel Glider is widely though sparsely distributed in eastern Australia, from northern Queensland to western Victoria. A few records also exist in south-east South Australia (OEH 2016b). It is generally rare and patchy in NSW, occurring on the North Coast and on the inland slopes, probably as two separate populations (NSW Scientific Committee 2008b). Hotspots for the species include the Clarence and lower Richmond Valleys, and the Central Coast (Kavanagh 2004). Some parts of the western slopes also support good populations, in particular the Nandewar Bioregion (NSW Scientific Committee 2008b). The Squirrel Glider was detected within the north-west of the study area and in the south in Pilliga East State Forest. Multiple previous records of the species exist from within and around the study area in the Pilliga East and Jacks Creek State Forests (OEH 2016a).

The Squirrel Glider is associated with eucalypt open forests and woodlands with a *Banksia* sp. or *Acacia sp.* shrub layer (van der Ree & Sucking 2008). The most important habitat features for the species are large trees with abundant hollows, and a good winter supply of nectar (Menkhorst et al. 1988). Prime habitat, on richer soils and gentle terrain, has been largely cleared or degraded. In the eastern Pilliga, the Squirrel Glider has been recorded from grassy woodland, heathy woodland, riparian woodland and shrub-grass woodland habitats. They are also predicted to occur in shrubby woodlands in the study area.

Within the study area, approximately 66,705 ha of habitat has been mapped which provides 66,705 ha of foraging habitat and 66,801 ha of breeding habitat. Within the study region, approximately 285,998 ha of habitat has been mapped which provides 285,998 ha of foraging habitat and 285,998 ha of breeding habitat. An upper limit of 861.80 ha of foraging and breeding habitat would be directly impacted which equates to 1.29% of foraging and breeding habitat in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 170.71 ha of foraging and breeding habitat which would combine to impact a total of 1.55% of both foraging and breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Eastern Pygmy Possum or Squirrel Glider at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the two assessed species lifecycle or which reduce habitat quality. In order to place the populations at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and nesting. Growth requires adequate habitat and conditions for nesting, foraging and communication. Development requires adequate habitat and conditions for nesting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and nesting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoidance and minimisation of removal of hollow-bearing trees and other important habitat features, staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would remove up to 774.80 ha of Eastern Pygmy Possum foraging and breeding habitat. This constitutes approximately 1.37% of foraging and breeding habitat removed in the study area. Up to 861.80 ha of Squirrel Glider foraging and breeding habitat would be removed. This constitutes approximately 1.29% of foraging and breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 153.01 ha of foraging and breeding habitat for Eastern Pygmy Possum and 170.71 ha of foraging and breeding habitat for Squirrel Glider. The direct and indirect impact on habitat would constitute a total impact of approximately 1.64% of foraging and breeding habitat for Eastern Pygmy Possum and 1.55% of foraging and breeding habitat for Squirrel Glider in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the two assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths may discourage movement, especially for Eastern Pygmy Possum. The linear clearing would not prevent movement by the two assessed species, but if individuals are forced to move on the ground to navigate open areas, they could become more susceptible to risks (collisions and predation).

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the two assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the two assessed species in the study region (the locality).

Both Eastern Pygmy Possum and Squirrel Glider have been recorded in the study area and would use the study area for foraging and breeding. The study area would maintain over 98% of habitat which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the two assessed species in the study region.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Eastern Pygmy Possum and Squirrel Glider have been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Eastern Pygmy Possum and have been discussed in relation to the project:

1. *Conduct field surveys using "Elliot" traps in trees and on the ground and pitfall traps to further delineate distribution and key populations. Avoid periods of cold weather. Areas identified for development should receive high priority.* Field surveys undertaken for this ecological assessment included arboreal and terrestrial Elliott trapping and pitfall trapping in the study area. As the specific footprint for development is not known, survey effort was distributed throughout suitable habitat in the study area.

2. *Control and monitor abundance of feral predators, especially cats, where there are known populations of EPP in areas of high quality habitat and encourage night-time curfews for cats on urban fringes adjacent to these habitats.* The feral animal control strategy proposed as part of the project would manage and monitor feral predators including feral cats and foxes in the study area. Urban cat populations are not relevant to the project.

3. *Provide map of known occurrences to Rural Fire Service and seek fire frequency of >10 years on Bush Fire Risk Management Plan(s), risk register and/or operation map(s).* All records of the Eastern Pygmy Possum have been and would continue to be supplied to OEH under the OEH licence agreement. These records would then be available to use as part of this management action.

4. *Encourage and support land managers to undertake management actions that benefit the species (see recovery information for land managers in our detailed species profile).* The project would undertake the following management actions as detailed in the profile: control feral predators and rabbits; protect habitat in proposed development areas and retain linkages across the broader landscape; and regenerate and replant local feed sources.

The following management actions are applicable for Squirrel Glider and have been discussed in relation to the project:

1. *Ensure the largest hollow bearing trees (including dead trees) are given highest priority for retention in PVP assessments and other environmental planning instruments, or other land assessment tools.* Data on 'diameter at breast height', number of hollows and hollow size would be collected during the pre-clearance survey. The ecological scouting framework takes this data into consideration when minimising removal of hollow-bearing trees.

Predation by foxes is listed as a threat for arboreal hollow-dependent fauna (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the two assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Competition from feral honey bees (*Apis mellifera*)
  - Invasion of native plant communities by exotic perennial grasses
  - Predation by the European Red Fox (*Vulpes vulpes*)

  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the pest and weed management plan would control the modification of the vegetation in the ground layer and ensure native plant species structure suitable for these species. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Eastern Pygmy Possum or Squirrel Glider. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Eastern Pygmy Possum or Squirrel Glider.

Predominantly tree-roosting bats

Chalinolobus picatus (Little Pied Bat), *Nyctophilus corbeni* (South-eastern Long-eared Bat) and *Saccolaimus flaviventris* (Yellow-bellied Sheathtail-bat) are considered in this assessment.

***Chalinolobus picatus* (Little Pied Bat)**

The Little-Pied Bat is found inland of the central Queensland coast, through western NSW and extending into far-eastern South Australia and north-west Victoria (OEH 2016b). The species has been detected within the study area, predominately in the north-western section of the study area, although the species was also recorded in the south, in Pilliga East State Forest and Bibblewindi State Forest.

The Little-Pied Bat is found in a wide range of habitats, including dry open forest, open woodland, mulga woodlands, chenopod shrublands, cypress-pine forest, mallee and Bimbil box woodland (OEH 2016b). It mainly roosts in tree hollows (Ford et al. 2008), but also uses caves, rock outcrops, mine shafts, tunnel and buildings. Known habitat for the species in the eastern Pilliga includes closed forest, grassy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. It is also predicted to utilise heath and heathy woodland in the study area.

Within the study area, approximately 70,933 ha of habitat has been mapped which provides 70,933 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 316,452 ha of habitat has been mapped which provides 316,452 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 912.90 ha of habitat would be directly impacted (912.90 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.29% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.54% of foraging habitat and 1.53% of breeding habitat in the study area.

***Nyctophilus corbeni* (South-eastern Long-eared Bat) – Vulnerable**

The distribution of the South-eastern Long-eared Bat coincides approximately with the Murray Darling Basin with the Pilliga Scrub region being the distinct stronghold for this species (OEH 2016b). Eight South-eastern Long-eared Bats were recorded at six sites in the study area during surveys for this assessment. The literature review obtained an additional 20 South-eastern Long-eared Bat records from eight sites in the study area. Previously, records for the South-eastern Long-eared Bat were only from the forested portion of the study area. The record from closed forest in the Brigalow Nature Reserve from this assessment is the first record in the northern portion of the study area.

The South-eastern Long-eared Bat inhabits a range vegetation types including mallee, buloke, brigalow, belah and box eucalypt-dominated communities. However, it is more common in the box, ironbark, and cypress pine woodlands that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland (OEH 2016b). In the study area, it is known to occur in closed forest, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitats, and is also predicted to utilise grassy woodland habitats. The species roosts in tree hollows, crevices and under loose bark (DotE 2016b).

All field survey records of South-eastern Long-eared Bat are from individuals caught in harp traps. Echolocation calls from this species cannot be differentiated from other species of the same genus (*Nyctophilus*). As there are more than one species from the *Nyctophilus* genus that occur in the study area, no conclusions from the echolocation data can be made in reference to the South-eastern Long-eared Bat.

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27% of both foraging and breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.53% of both foraging and breeding habitat in the study area.

Saccolaimus flaviventris **(Yellow-bellied Sheathtail-bat) – Vulnerable**

The Yellow-bellied Sheathtail-bat is a wide-ranging species found across northern and eastern Australia. There are scattered records of this species across the New England Tablelands and North West Slopes. The species has been recorded extensively throughout the study area.

The Yellow-bellied Sheathtail-bat is found in almost all habitats, from wet and dry sclerophyll forest, open woodland, open country, mallee, rainforests, heathland and waterbodies (Churchill 2008). It forages for insects above the canopy in eucalypt forests, and closer to the ground in more open country. It is dependent on suitable hollow-bearing trees to provide roost sites, which may be a limiting factor on populations in cleared or fragmented habitats (Duncan et al. 1999). The species has also been recorded using caves and abandoned sugar glider nests as roost sites (Churchill 2008). In the eastern Pilliga, the Yellow-bellied Sheathtail-bat is known to use closed forest, grassy woodland, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitats. Grassland and heath are predicted to also be used by the species in the study area.

Within the study area, approximately 80,398 ha of habitat has been mapped which provides 80,398 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 350,758 ha of habitat has been mapped which provides 350,758 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.46% of foraging habitat and 1.53%of breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Little Pied Bat, South-eastern Long-eared Bat or Yellow-bellied Sheathtail Bat at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the three assessed species lifecycle or which reduce habitat quality. In order to place the populations at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and roosting. Growth requires adequate habitat and conditions for roosting, foraging and communication. Development requires adequate habitat and conditions for roosting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoidance and minimisation of removal of hollow-bearing trees and other important habitat features, staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2.	***In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
II.	***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and***
III.	***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality***

I. The project would directly remove the following amount of breeding and foraging habitat for the three assessed species:

- Little Pied Bat: 912.90 ha of habitat (912.90 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.29% of foraging habitat and 1.27% of breeding habitat in the study area.
- South-eastern Long-eared Bat: 885.00 ha of habitat (885.00 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.27% of foraging and breeding habitat in the study area.
- Yellow-bellied Sheathtail-bat: 988.80 ha of habitat (988.80 ha of foraging habitat and 885.00 ha of breeding habitat). This constitutes approximately 1.23%% of foraging habitat and 1.27% of breeding habitat in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss the following amounts of foraging and breeding habitat for the three assessed species:

- Little Pied Bat: 181.11 ha of habitat (181.11 ha of foraging and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.54% of foraging habitat and 1.53% of breeding habitat in the study area.
- South-eastern Long-eared Bat: 175.41 ha of habitat (175.41 ha of foraging habitat and breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.53% of foraging and breeding habitat in the study area.
- Yellow-bellied Sheathtail-bat: 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat). The additional indirect impact combines with direct impacts to constitute a total impact of 1.46% of foraging habitat and 1.53% of breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the three assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the three assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the three assessed species in the study region (the locality).

All three assessed species have been recorded in the study area and would use the study area for foraging and breeding. The study area would maintain over 98% of habitat which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the three assessed species in the study region.

Hollow-bearing trees are an important habitat feature for the three assessed species. Using the ecological scouting framework to avoid and minimise removing hollow-bearing trees where possible during design is an important measure for maintaining important habitat in the study area.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Under the Saving our Species program, Little Pied Bat has been assigned as a data-deficient species and both the South-eastern Long-eared Bat and Yellow-bellied Sheathtail-bat have been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Little Pied Bat and have been discussed in relation to the project:

1. *Conduct targeted research to investigate the species' habitat suitability and roosting requirements as well as general ecology, life history and population dynamics.* Field surveys for this ecological assessment were undertaken in foraging habitat for this species. Environmental features were recorded in each habitat type and habitat types were mapped in for the study area. Data obtained included body size, sex and breeding status. Additionally, the biodiversity monitoring proposed to be undertaken as part of the project would continue to record this data as well as abundance and distribution.

2. *Ensure the largest hollow bearing trees and standing dead trees (inc. small dead trees such as mulga, gidgee, leopardwood) are given highest priority for retention in PVP assessments or other land assessment tools.* Data on ‘diameter at breast height’, number of hollows and hollow size would be collected during the pre-clearance survey. The ecological scouting framework takes this data into consideration when minimising removal of hollow-bearing trees and standing dead trees.

3. *Undertake long-term monitoring of populations cross tenure in conjunction with other bat species to document changes.* The biodiversity monitoring proposed to be undertaken as part of the project would occur over a minimum of 30 years.

4. *Study the ecology and habitat requirements in different western environments such as mallee, mulga, "invasive native scrub" and ironbark-cypress forest.* Field surveys for this ecological assessment were undertaken in habitat for this species. Environmental features were recorded in each habitat type and habitat types were mapped in for the study area. Habitats surveyed included ironbark-cypress forest. Data obtained included body size, sex and breeding status. Additionally, the biodiversity monitoring proposed to be undertaken as part of the project would continue to record this data as well as abundance and distribution.

The following management actions are applicable for South-eastern Long-eared Bat and have been discussed in relation to the project:

5. *Encourage retention of the largest hollow-bearing trees.* Data on ‘diameter at breast height’, number of hollows and hollow size would be collected during the pre-clearance survey. The ecological scouting framework takes this data into consideration when minimising removal of hollow-bearing trees.

6. *Study the biology, ecology and habitat requirements of the species in different western environments, such as mallee and ironbark-cypress forest.* Field surveys for this ecological assessment were undertaken in habitat for this species. Environmental features were recorded in each habitat type and habitat types were mapped in for the study area. Habitats surveyed included ironbark-cypress forest. Data obtained included body size, sex and breeding status. Additionally, the biodiversity monitoring proposed

to be undertaken as part of the project would continue to record this data as well as abundance and distribution.

7. *Research the effects of fragmentation, including genetic isolation, movement among fragments and persistence in fragments that vary in size and connectivity.* The biodiversity monitoring proposed to be undertaken as part of the project would record abundance, distribution and signs of health. This data would indicate the species' response to impacts including fragmentation.

8. *Undertake long-term monitoring of populations across tenures.* The biodiversity monitoring proposed to be undertaken as part of the project would occur over a minimum of 30 years.

9. *Encourage the protection and enhancement of understorey vegetation.* Approximately 98% of habitat in the study area would not be directly or indirectly impacted. This vegetation would not be subject to additional industrial pressures and would be able to be enhanced over time.

10. *Conduct surveys in preferred and potential habitat throughout the species range.* Field surveys for this ecological assessment were undertaken in known and potential habitat for this species.

The following management actions are applicable for Yellow-bellied Sheathtail-bat and have been discussed in relation to the project:

1. *Ensure the largest hollow bearing trees (including dead trees and paddock trees) are given highest priority for retention in PVP assessments and or other land assessment tools.* Data on 'diameter at breast height', number of hollows and hollow size would be collected during the pre-clearance survey. The ecological scouting framework takes this data into consideration when minimising removal of hollow-bearing trees.

2. *Undertake long-term monitoring of populations cross tenure in conjunction with other bat species to document changes.* The biodiversity monitoring proposed to be undertaken as part of the project would occur over a minimum of 30 years.

3. *Identify the effects of fragmentation on the species in a range of fragmented landscapes.* The biodiversity monitoring proposed to be undertaken as part of the project would record abundance, distribution and signs of health. This data would indicate the species' response to impacts including fragmentation.

Predation by foxes is listed as a threat for the tree-roosting bats (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the assessed species:

- Invasive species
  - Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Competition from feral honey bees (*Apis mellifera*)
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
  - Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).
- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Little Pied Bat, South-eastern Long-eared Bat or Yellow-bellied Sheathtail-bat. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Little Pied Bat, South-eastern Long-eared Bat or Yellow-bellied Sheathtail-bat.

Predominantly cave-roosting bats

Chalinolobus dwyeri (Large-eared Pied Bat), *Miniopterus schreibersii oceanensis* (Eastern Bentwing-bat) and *Vespadelus troughtoni* (Eastern Cave Bat) are considered in this assessment.

***Chalinolobus dwyeri* (Large-eared Pied Bat)**

The distribution of the Large-eared Pied Bat is poorly known. Records exist from Rockhampton in Queensland south to Ulladulla in NSW. Much of the known range of the species is within NSW, although it is uncommon with a very patchy distribution. Available records suggest that the largest concentrations of populations occur in the sandstone escarpments of the Sydney basin and the north-west slopes (Coolah Tops, Mt Kaputar, Warrumbungle National Park and Pilliga Nature Reserve; DoE 2014).

The Large-eared Pied Bat has been recorded in a variety of habitats, including wet and dry sclerophyll forests, cypress pine dominated forest, woodland, sub-alpine woodland, edges of rainforests and sandstone outcrop country (DotE 2016b). This species roosts in caves, rock overhangs and disused mine shafts and as such is usually associated with rock outcrops and cliff faces (Churchill 2008). It also possibly roosts in the hollows of trees (Duncan et al. 1999). The species is thought to require roosting habitat that is adjacent to higher fertility sites, particularly box gum woodlands or river corridors, which are used for foraging. In the study area, the Large-eared Pied Bat is predicted to utilise grassy, heathy, shrubby, riparian and shrub-grass woodland habitat.

The number of known breeding sites is limited. No maternity roosts have been recorded in the study area. A maternity roost has been observed in a sandstone cave near Coonabarabran, NSW (Pennay 2008), and another nearby in the Pilliga sandstone (M. Pennay *pers. comm.* 2010 cited in DERM 2011). Small groups of females and young bats have been observed in the Pilliga Scrub (DERM 2011). Young have also been noted in a small group of females in a disused gold mine near Barraba, NSW (P. Spark *pers. comm.* 2011 cited in DERM 2011).

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and an unknown amount of breeding habitat. An upper limit of 885.00 ha of foraging habitat would be directly impacted which equates to 1.27% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of foraging habitat would be indirectly which would combine to impact a total of 1.53% foraging habitat in the study area.

***Miniopterus schreibersii oceanensis* (Eastern Bentwing-bat)**

The Eastern Bentwing-bat occurs along the east and north-west coasts of Australia (OEH 2016b). In NSW it occurs on both sides of the Great Dividing Range, from the coast inland to Moree, Dubbo and Wagga Wagga. There are records of the species from the Kaputar Ranges to the north-east of the study area (OEH 2016a). Within the study area, most records are from the southern end of the study site in Pilliga East State Forest and Bibblewindi State Forest, but there is also a record from near Yarrie Lake in the north-west.

The Eastern Bentwing-bat is associated with a range of habitats: rainforest, wet and dry sclerophyll forest, monsoon forest, open woodland, paperbark forests and open grassland (Churchill 2008). It forages above and below the tree canopy (Dwyer 1981; Dwyer 1995). In the eastern Pilliga, the species is known to use closed forest, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. It is also predicted to utilise all other habitat types in the study area (water bodies, grassland, grassy woodland and heath). There are no known maternity roosts in the study area. Over-wintering roosts used outside the breeding period include cooler caves, old mines, and stormwater channels, under bridges and occasionally buildings (Duncan et al. 1999; Dwyer 1995).

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and an unknown amount of breeding habitat. An upper limit of 988.80 ha of foraging habitat would be directly impacted which equates to 1.23% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of foraging habitat which would combine to impact a total of 1.45% of foraging habitat in the study area.

Vespadelus troughtoni (Eastern Cave Bat)

The Eastern Cave Bat is found in a broad band on both sides of the Great Dividing Range from Cape York in Queensland to Kempsey in NSW. In NSW, there are records of the species from the New England Tablelands and the upper north coast. The western limit appears to be the Warrumbungle Range, and there is a single record from southern NSW, east of the ACT (OEH 2016b). The species has been recorded at several locations across the southern and north-west portions of the study area.

The species inhabits tropical woodland and wet sclerophyll forest in coastal areas, but extends into the drier forests and woodlands of the western slopes and inland areas (Churchill 2008). It has been found roosting in sandstone overhand caves, boulder piles, mine tunnels and occasionally in buildings (Churchill 2008; Parnaby et al. 2008). In the eastern Pilliga, known habitat for the Eastern Cave Bat encompasses closed forest, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland. It is also predicted to utilise grassy woodland habitats in the study area.

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and an unknown amount of breeding habitat. An upper limit of 885.00 ha of foraging habitat would be directly impacted which equates to 1.27% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of foraging habitat which would combine to impact a total of 1.53% of foraging habitat in the study area.

1.	***In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The project is unlikely to place a viable local population of the Large-eared Pied Bat, Eastern Bentwing-bat or Eastern Cave Bat at risk of extinction through an adverse effect on the lifecycle of these species (reproduction, growth, development, aging and death).

The three assessed species do not have breeding or roosting habitat in the study area as they breed and roost predominantly in caves. Hence the reproduction and growth phases of their lifecycle are not affected by activities in the study area.

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the three assessed species lifecycle or which reduce habitat quality. In order to place the populations at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Development requires adequate habitat and conditions for roosting, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions to maintain foraging and roosting. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and not directly or indirectly impacting over 98% of foraging habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2.	***In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

3.	***In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:***
I.	***Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
II.	***Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***

Not applicable.

4.	***In relation to the habitat of a threatened species, population or ecological community:***
I.	***the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would directly remove the following amount of foraging habitat for the three assessed species:

- Large-eared Pied Bat: 885.00 ha of foraging habitat which constitutes approximately 1.27% of foraging habitat in the study area.
- Eastern Bentwing-bat: 988.80 ha of foraging habitat which constitutes approximately 1.23% of foraging habitat in the study area.
- Eastern Cave Bat: 885.00 ha of foraging habitat which constitutes approximately 1.27% of foraging habitat in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss the following amounts of foraging habitat for the three assessed species:

- Large-eared Pied Bat: 175.41 ha of foraging habitat. The additional indirect impact combines with direct impacts to constitute a total impact of 1.53% of foraging habitat in the study area.
- Eastern Bentwing-bat: 181.11 ha of foraging habitat. The additional indirect impact combines with direct impacts to constitute a total impact of 1.45% of foraging habitat in the study area.
- Eastern Cave Bat: 175.41 ha of foraging habitat. The additional indirect impact combines with direct impacts to constitute a total impact of 1.53% of foraging habitat in the study area.

II. Additional fragmentation of foraging habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the three assessed species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the three assessed species would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging habitat, it is not considered important for the long-term survival of the three assessed species in the study region (the locality).

Eastern Bentwing-bat and Eastern Cave Bat have been recorded in the study area and would use the study area for foraging. Large-eared Pied Bat is considered to potentially use the study area for foraging. The study area would maintain over 98% of habitat which could continue to support foraging in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the three assessed species in the study region.

5. *Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).*

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for the assessed species in the study area.

6. *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

Under the Saving our Species program, Large-eared Pied Bat has been assigned as a data-deficient species, the Eastern Bentwing-bat has been assigned a site-managed species and the Eastern Cave Bat has been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

Four sites have been assigned for management of the Eastern Bentwing-bat. Conservation at these four sites is considered important for the long-term conservation of the species. The study area is not within these sites and therefore there are no actions relevant to the study area.

The following management actions are applicable for Large-eared Pied Bat and have been discussed in relation to the project:

1. *Investigate the environmental features that predict occupancy.* Field surveys for this ecological assessment were undertaken in potential foraging habitat for this species. Environmental features were recorded in each habitat type and habitat types were mapped in for the study area. This data will be applicable to this management action if this species is confidently recorded in the study area. Additionally the literature review recorded habitat information for previous records of this species if possible.

The following management actions are applicable for Eastern Cave Bat and have been discussed in relation to the project:

1. *Control feral goats in rock overhangs and caves in the species range.* A high number of feral goats were observed in the rocky outcrop east of the study area. The feral animal control strategy proposed as part of the project would manage and monitor goats. It is proposed that the strategy is applied at a landscape scale which would reach goat populations extending beyond the study area.

2. *Survey areas of potential habitat.* The study area has habitat considered both potential and known occurrence for this species. Field surveys for this ecological assessment were undertaken across the study area in potential foraging habitat for this species. Additionally, the biodiversity monitoring proposed to be undertaken as part of the project would continue survey potential habitat of this species.

Predation by foxes is listed as a threat for cave-roosting bats (OEH 2016b) and hence the threat abatement plan for predation by the European Red Fox (DEWHA 2008) is relevant. The four objectives of the threat abatement plan are:

1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation

2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species

3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes

4. Provide support for the implementation of the plan.

These objectives relate to the control of foxes and the feral animal control strategy proposed as part of the project would be consistent with these objectives.

7. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The following key threatening processes are likely to occur and are relevant to the two assessed species:

- Invasive species
  - Competition and habitat degradation by feral goats (*Capra hircus*)
  - Predation by the European Red Fox (*Vulpes vulpes*)
  - Predation by the feral cat (*Felis catus*)
  - Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
- Direct impact
  - Clearing of native vegetation
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the invasive species and direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the feral animal control strategy proposed as part of the project would reduce the pressure of feral animals in the study area. The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Large-eared Pied Bat, Eastern Bentwing-bat or Eastern Cave Bat. The direct and indirect impact of less than 2% of the foraging habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Large-eared Pied Bat, Eastern Bentwing-bat or Eastern Cave Bat.

1.6 Reptiles

Hoplocephalus bitorquatus (Pale-headed Snake) – vulnerable

The Pale-headed Snake has a patchy distribution from north-east Queensland to north-east NSW. In NSW, it occurs from the coast to the western side of the Great Divide as far south as Tuggerah (OEH 2016b). Historically, it has been recorded as west as Mungindi and Quambone on the Darling Riverine Plains, across the North West Slopes, and has also been recorded from the New England Tablelands. The Pale-headed snake was detected in the north-west of the study area. One additional previous record occurs in the south of the study area in Pilliga East State Forest (Landmark Ecological Services & The Wilderness Society 2012).

The species is found mainly in dry eucalypt forests and woodlands and cypress woodland (OEH 2016b) . It favours streamside areas, particularly in drier habitats. Individuals shelter during the day between loose bark and tree-trunks, or in hollow trunks and limbs of dead trees (OEH 2016b). Their cryptic nature means they are difficult to observe, and may attribute to the low number of records of the species in the Pilliga. In the study area, two Pale-headed Snake were observed in trees, one in a hollow in shrub grass woodland with a canopy of *Eucalyptus pilligaensis* and *Eucalyptus populnea* and the other in a *Eucalyptus camaldulensis* on the edge of Yarrie Lake. The two other records were of Pale-headed Snake moving on the ground, one in closed forest in the Brigalow Nature Reserve and the other in a thin strip of closed forest, adjacent to the road. In the literature review, Pale-headed Snake was also trapped in the study area using a snake funnel in heathy woodland. Predicted habitat in the study area includes grassy woodland and shrubby woodland.

Of all the records in the study area, only the record from Yarrie Lake is in habitat proximate to a water source. These results indicate that Pale-headed Snake habitat in the study area is not dependent on water sources and hence all habitat types in the study area with a canopy layer supporting hollows, loose bark or stags are considered suitable habitat for the Pale-headed Snake.

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27% of foraging and breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.53% of both foraging and breeding habitat in the study area.

1. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The project is unlikely to place a viable local population of the Pale-headed Snake at risk of extinction through an adverse effect on the lifecycle of this species (reproduction, growth, development, aging and death).

Lifecycle can be impacted by direct impacts of habitat removal (discussed in question 4) or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the Pale-headed Snake lifecycle or which reduce habitat quality. In order to place the populations at risk of extinction in the study area, the impacts would have to be of a magnitude and duration that would inhibit the continual completion of the lifecycle stages.

Reproduction requires adequate habitat and conditions for communication, mating and refuge. Growth requires adequate habitat and conditions for refuge, foraging and communication. Development requires adequate habitat and conditions for refuge, foraging, communication, maturation and dispersal. Aging requires adequate habitat and conditions for foraging and refuge. Death is not considered a stage of the lifecycle which needs to be assessed.

Impacts to the lifecycle would be mitigated by avoidance and minimisation of removal of hollow-bearing trees and other important habitat features, staged construction, progressive rehabilitation and not directly or indirectly impacting over 98% of habitat in the study area. Reproduction, growth, development and aging would be still able to be carried out in the study area during all stages of the project.

2. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

3. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

I. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

II. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable.

4. In relation to the habitat of a threatened species, population or ecological community:

I. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

II. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed activity, and

III. the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

I. The project would remove up to 885.00 ha of Pale-headed Snake foraging and breeding habitat. This constitutes approximately 1.27% of foraging and breeding habitat removed in the study area.

The project has potential to modify additional habitat as a result of indirect impacts. The reduction in habitat quality would be comparable to the loss of a further 175.41 ha of foraging and breeding habitat for Pale-headed Snake The direct and indirect impact on habitat would constitute a total impact of approximately 1.53% of foraging and breeding habitat in the study area.

II. Additional fragmentation of foraging and breeding habitat would occur as a result of the project. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the Pale-headed Snake would have the mobility to move between patches. Pale-headed Snake were observed moving through open grassland adjacent to existing roads in the study area. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Pale-headed Snake would be possible around the infrastructure.

III. Whilst the habitat to be directly or indirectly impacted provides foraging and breeding habitat, it is not considered necessary for the long-term survival of the Pale-headed Snake in the study region (the locality).

Pale-headed Snake have been recorded in the study area and would use the study area for foraging and breeding. The study area would maintain over 98% of habitat which could continue to support foraging and breeding in the study area. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region (the locality). Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to impact the long-term survival of the Pale-headed Snake in the study region.

Hollow-bearing trees are an important habitat feature for the Pale-headed Snake. Using the ecological scouting framework to avoid removing hollow-bearing trees where possible during design is an important measure for maintaining important habitat in the study area.

5. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no critical habitat listed on the register of critical habitat (OEH 2013) relevant for Pale-headed Snake in the study area.

6. *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

Under the Saving our Species program, Pale-headed Snake has been assigned as landscape species. A species action statement has been prepared and replaces the requirement to prepare a recovery plan (DECC 2007).

The following management actions are applicable for Pale-headed Snake and have been discussed in relation to the project:

1. *Retain, rehabilitate or create corridors to reduce isolation between sub-populations.* Habitat in the study area would not be isolated as a result of the project such that this species would be further isolated into sub-populations. Individuals in the north of the study area near Yarrie Lake and Brigalow Nature Reserve are currently in habitat fragmented from each other and from the Pilliga forests.

2. *Conduct further research into the ecology and habitat requirements of the species in NSW.* The majority of records of Pale-headed Snake from field surveys for this ecological assessment were recorded in habitat not previously thought to be likely to support the species in the study area. Only one record was proximal to a water source. The biodiversity monitoring proposed to be undertaken as part of the project would continue survey potential habitat of this species.

3. *Provide map of known occurrences to Rural Fire Service and seek inclusion of mitigative measures on Bush Fire Risk Management Plan(s), risk register and/or operation map(s).* All records of the Pale-headed Snake have been and would continue to be supplied to OEH under the OEH licence agreement. These records would then be available to use as part of this management action.

7. *Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The following key threatening processes are likely to occur and are relevant to the Pale-Headed Snake assessed species:

- Direct impact
  - Clearing of native vegetation
  - Loss of hollow-bearing trees
  - Removal of dead wood and dead trees.
- Environmental modification
  - High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

Of the above key threatening processes, the direct impact key threatening processes already exist in the study area. However, it is likely that the project could exacerbate these key threatening processes.

The implementation of the ecological scouting framework and the co-location of linear infrastructure along existing roads where possible would minimise the removal of native vegetation, hollow-bearing trees, dead wood and dead trees in the study area. The implementation of a bushfire hazard and risk assessment would minimise the chance of bushfire caused by the project.

Conclusion

The project is considered unlikely to have a significant impact on the Pale-headed Snake. The direct and indirect impact of less than 2% of the foraging and breeding habitat in the study area is not considered significant and is unlikely to cause a viable population to become extinct in the short or long term.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, it is unlikely that the project will significantly impact on the Pale-headed Snake.

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Appendix K: Assessment of significance under the EPBC Act

This following appendix provides an assessment of the potential significance of impacts from the proposed activity on matters of national environmental significance (MNES). The EPBC Act Matters of National Environmental Significance Significant Impact Guidelines (EPBC Act Significant Impact Guidelines) (DotE 2013c) set out ‘Significant Impact Criteria’ that are to be used to assist in determining whether a proposed action is likely to have a significant impact on matters of national environmental significance and subsequently the need for referral.

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 a referral has already been prepared, the EPBC Significant Impact Guidelines were used as a framework to guide detailed impact assessment for matters of national environmental significance as part of the Environmental Impact Statement for the project.

The following definitions are used in the following assessments of significance and are obtained from the EPBC Act Significant Impact Guidelines:

- Extent of an ecological community: refers to the geographic extent.
- Habitat critical to the survival of a species: areas that are necessary for activities such as foraging, breeding, roosting or dispersal; for the long-term maintenance of the species or ecological community (including the maintenance of species essential to the survival of the species or ecological community, such as pollinators); to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species or ecological community. Such habitat may be, but is not limited to habitat identified in a recovery plan for the species or ecological community as habitat critical for the species or ecological community; and/or habitat listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.
- Important habitat: habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or habitat that is of critical importance to the species at particular life-cycle stages, and/or habitat utilised by a migratory species which is at the limit of the species range, and/or habitat within an area where the species is declining.
- Important population: a population that is necessary for a species’ long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are key source populations either for breeding or dispersal; populations that are necessary for maintaining genetic diversity; and/or populations that are near the limit of the species range.
- Population: an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable species, occurrences include but are not limited to: a geographically distinct regional population, or collection of local populations or a population, or collection of location populations, that occurs within a particular bioregion. In relation to migratory species, means the entire population or geographically separate parts of the population of species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries including Australia.
- Invasive species: an introduced species, including an introduced (translocated) native species, which out-competes native species for space and resources or which is a predator of native species.

- Ecologically significant proportion: listed migratory species cover a broad range of species with different life cycles and population sizes. Therefore, what is an ‘ecologically significant proportion’ of the population varies with the species (each circumstance will need to be evaluated). Some factors that should be considered include the species’ population status, genetic distinctiveness and species specific behavioural patterns (for example, site fidelity and dispersal rates).

MNES considered relevant to this assessment include:

Ecological communities – Endangered

- Brigalow (*Acacia harpophylla* dominant and co-dominant)
- Weeping Myall Woodlands

Flora – Vulnerable

- *Bertya opponens* (Coolabah Bertya)*, Lepidium aschersonii* (Spiny Peppercress) and *Androcalva procumbens.*

Flora – Endangered

- *Lepidium monoplocoides* (Winged Peppercress) and *Tylophora linearis*

Birds – Vulnerable

- *Grantiella picta* (Painted Honeyeater), *Polytelis swainsonii* (Superb Parrot)

Birds – Endangered

- *Botaurus poiciloptilus* (Australasian Bittern), and *Rostratula australis* (Australian Painted Snipe; also marine)

Birds – Critically Endangered

- *Anthochaera phrygia* (Regent Honeyeater), *Lathamus discolor* (Swift Parrot; also marine)

Mammals– Vulnerable

- *Chalinolobus dwyeri* (Large-eared Pied Bat), *Nyctophilus corbeni* (South-eastern Long-eared Bat), *Phascolarctos cinereus* (Koala) and *Pseudomys pilligaensis* (Pilliga Mouse)

Mammals – Endangered

- *Dasyurus maculatus* (Spotted-tailed Quoll)

Migratory species

- *Apus pacificus* (Fork-tailed Swift), *Ardea ibis* (Cattle Egret), *Ardea modesta* (Great Egret), *Calidris acuminata* (Sharp-tailed Sandpiper), *Gallinago hardwickii* (Latham's Snipe), *Hirundapus caudacutus* (White-throated Needletail), *Merops ornatus* (Rainbow Bee-eater), *Myiagra cyanoleuca* (Satin flycatcher) and *Plegadis falcinellus* (Glossy Ibis)

1.1 Ecological communities

Brigalow (Acacia harpophylla dominant and co-dominant) – Endangered

This community is characterised by the presence of Brigalow (*Acacia harpophylla*) as one of the three most abundant tree species (Butler 2007). Brigalow is usually either dominant in the tree layer or co-dominant with other species such as *Casuarina cristata* (Belah), or other *Acacia* or *Eucalyptus* species. The structure of the vegetation ranges from open forest to open woodland, and usually includes a prominent shrub layer (DotE 2016b). In NSW, Brigalow woodlands are typically associated with: red, brown and grey clays; red and grey earths; and, red-brown earths (Benson et al. 2006).

Brigalow (*Acacia harpophylla* dominant and co-dominant) is found mostly west of the Great Dividing Range, stretching in a broad swathe east of Blackall, Charleville and Cunnamulla, north almost to Townsville in Queensland, south to Narrabri in NSW, and west to Bourke on the Darling River and Blackall in central western Qld. In NSW, remnants of the listed ecological community mostly occur north of Bourke, west of Narrabri and north of Moree (Butler 2007). Other minor occurrences are found near Walgett and Gunnedah, at Mt Misery and in the Pilliga East State Forest (Benson 2006). This community is known to occur within the north of the study area, predominantly in remnant patches in Brigalow State Conservation Area and along roadsides. It also occurs in Brigalow Nature Reserve which is outside of the study area.

There are 2,468 ha of the community mapped in the study area and 8,704 ha of the community mapped in the study region. An upper limit of 19.30 ha would be directly impacted which equates to 0.78% directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 3.90 ha which would combine to impact a total of 0.94% in the study area.

An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:

Reduce the extent of an ecological community

The project is unlikely to reduce the extent of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community. The extent of this ecological community in the study area is confined to the north of the study area and over 99% of this ecological community would not be removed or indirectly impacted. The geographical extent would not be contracted as a result of the project. Using the ecological scouting framework, areas of this ecological community would be avoided where possible which would minimise the extent directly and indirectly impacted.

Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines

The Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community is currently fragmented from agricultural practices in the north of the study area. The project is likely to increase fragmentation of this ecological community to a degree and it is likely that additional patches of this community would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. This community would not be intersected by the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked as pollination and dispersal of species in this ecological community could still occur between patches.

Adversely affect habitat critical to the survival of an ecological community

Up to 0.94% of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area would be directly or indirectly impacted by the project. The approved conservation advice for this ecological community (DotE 2013a) stipulates that area critical to the survival of this ecological community includes *'all patches that meet the key diagnostic characteristics and condition thresholds for the ecological community; plus the buffer zones, particularly where these include native vegetation.'* All patches of this community mapped in the study area meet the key diagnostic characteristics and condition thresholds and are therefore considered critical habitat.

Habitat for this community is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.

Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns

The project is unlikely to modify or destroy abiotic factors necessary for the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community's survival. The soil would be modified in up to 0.78% of the ecological community directly impacted. The topsoil at the well pads would be removed, stored and managed for use during rehabilitation. The topsoil along the gathering system would remain in-situ as part of the immediate rehabilitation after disturbance. Approximately 55% of the well pads and 50% of the gathering system would be rehabilitated as soon as possible after the construction phase. The remaining area would be rehabilitated following completion of the operation phase.

The flow of surface water has been mapped by using both defined watercourses and buffers (as defined by the NSW *Water Management Act 2000*) and the one in one hundred year flood zone. Well pads would not be placed in riparian corridors whilst placement of the gathering system would be designed to cross these areas perpendicularly where possible. Infrastructure within the one in one hundred flood zone would be designed appropriately to not be impacted by, and not impede a one in one hundred year flood.

The groundwater levels in the study area are not predicted to be significantly affected and are therefore unlikely to cause changes to water availability for this ecological community.

Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting

The project is unlikely to cause a substantial change in the species composition of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area. The composition of this community may be modified in areas that are indirectly impacted. The indirect impact would be comparable to removing 0.16% of this community in the study area. Over 99% of this community will not be directly or indirectly impacted and hence would not be adversely modified in composition. Vegetation clearing would be documented to ensure that clearing limits are not surpassed.

Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to: assisting invasive species, that are harmful to the listed ecological community, to become established, or

The project is unlikely to cause a substantial reduction in the quality or integrity of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area. Invasive species that have potential to impact this ecological community are currently established in the study area (including rabbits, goats, pigs and weeds). It is possible that the spread of weed species would occur by increased movement of people and machinery in the study area. It is also possible that feral fauna would benefit from the increased construction of roads and disturbance to native vegetation. However, the feral animal control strategy and the pest and weed management plan proposed to be implemented as part of the project would manage and monitor invasive species, ensuring that quality or integrity of this ecological community isn't substantially reduced.

Causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community, or

The project is unlikely to cause regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community. Accidental spills and leaks of drilling fluid, cement, hydrocarbons and other substances have the potential to impact this ecological community.

Provided adequate casing, bunding and erosion and sediment control protection is installed, accidental spills and leaks are unlikely to significantly affect surrounding vegetation including this ecological community.

Interfere with the recovery of an ecological community.

The project is unlikely to interfere substantially with the recovery of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this ecological community in the study area including its distribution, species diversity and abundance and possible or observed threats. Monitoring would ensure that proposed mitigation measures are substantially managing this ecological community and would trigger additional actions if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area, despite the potential for the project to adversely affect habitat critical to the survival of the community.

Over 99% of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area would not be directly or indirectly impacted and it is unlikely that the extent or condition would be substantially changed.

The removal of 19.30 ha of the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches, nor are abotic factors necessary for the survival of the community likely to be modified or destroyed

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this ecological community are not considered likely to impact its long-term survival in the study area.

Despite this conclusion, residual impacts of the project on Brigalow (*Acacia harpophylla* dominant and co-dominant) will be offset in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

Weeping Myall Woodlands – Endangered

The Weeping Myall Woodlands ecological community ranges from an open woodland to woodland, generally 4-12 m high, in which *Acacia pendula* (Weeping Myall) trees are the sole or dominant overstorey species. Other tree species may include *Alectryon oleifolius* subsp. *elongatus* (Western Rosewood); *Eucalyptus populnea* (Poplar Box); or *Eucalyptus largiflorens* (Black Box) (NSW Scientific Committee 2005; Keith 2004). The understorey often includes an open layer of shrubs above an open ground layer of grasses and herbs; however, in many areas the shrub layer has disappeared through overgrazing and the woodland now has a primarily grassy understorey (Threatened species scientific committee 2008).

The ecological community occurs on the inland alluvial plains west of the Great Dividing Range in NSW and Queensland. It occurs in the Riverina, NSW South Western Slopes, Darling Riverine Plains, Brigalow Belt South, Brigalow Belt North, Murray-Darling Depression, Nandewar and Cobar Peneplain Bioregions. The community generally occur on flat areas, shallow depressions or gilgais on raised alluvial plains, on black, brown, red-brown or grey clay or clay loam soils (Threatened species scientific committee 2008).

Weeping Myall Woodlands occur in the north of the study area, on private land west of Yarrie Lake. There are 36 ha of the community mapped in the study area and 126 ha of the community mapped in the study region. An upper limit of 0.10 ha would be directly impacted which equates to 0.28% directly impacted in the study area. No additional indirect impacts will result from the project.

An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:

Reduce the extent of an ecological community

The project is unlikely to reduce the extent of the Weeping Myall Woodlands ecological community. The extent of this ecological community in the study area is confined to the north of the study area and over 99% of this ecological community would not be removed or indirectly impacted. The geographical extent would not be contracted as a result of the project. Using the ecological scouting framework, areas of this ecological community would be avoided where possible which would minimise the extent directly and indirectly impacted.

Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines

The Weeping Myall Woodlands ecological community is currently fragmented from agricultural practices in the north of the study area. The project is likely to increase fragmentation of this ecological community to a degree and it is likely that additional patches of this community would be formed. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. This community would not be intersected by the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked as pollination and dispersal of species in this ecological community could still occur between patches.

Adversely affect habitat critical to the survival of an ecological community

Habitat for Weeping Myall Woodlands ecological community is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this ecological community.

Using the definition for this assessment, all area mapped as this ecological community in the study area is considered critical to the survival of the ecological community as it is necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species which make up this ecological community. Up to 0.28% of habitat critical to the survival of this ecological community in the study area would be directly or indirectly impacted.

Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns

The project is unlikely to modify or destroy abiotic factors necessary for the Weeping Myall Woodlands ecological community's survival. The soil would be modified in up to 0.28% of the ecological community which will be directly impacted. The topsoil at the well pads would be removed, stored and managed for use during rehabilitation. The topsoil along the gathering system would remain in-situ as part of the immediate rehabilitation after disturbance. Approximately 55% of the well pads and 50% of the gathering system would be rehabilitated as soon as possible after the construction phase. The remaining area would be rehabilitated following completion of the operation phase.

The flow of surface water has been mapped by using both defined watercourses and buffers (as defined by the NSW *Water Management Act 2000*) and the one in one hundred year flood zone. Well pads would not be placed in riparian corridors whilst placement of the gathering system would be designed to cross these areas perpendicularly where possible. Infrastructure within the one in one hundred flood zone would be designed appropriately to not be impacted by, and not impede a one in one hundred year flood.

The groundwater levels in the study area are not predicted to be significantly affected and are therefore unlikely to cause changes to water availability for this ecological community.

Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting

The project is unlikely to cause a substantial change in the species composition of the Weeping Myall Woodlands ecological community in the study area. Over 99% of this community in the study area would not be directly or indirectly impacted and hence would not be adversely modified in composition. Vegetation clearing would be documented to ensure that clearing limits are not surpassed.

Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to: assisting invasive species, that are harmful to the listed ecological community, to become established, or

The project is unlikely to cause a substantial reduction in the quality or integrity of the Weeping Myall Woodlands ecological community in the study area. Invasive species that have potential to impact this ecological community are currently established in the study area (including rabbits, goats, pigs and weeds). It is possible that the spread of weed species would occur by increased movement of people and machinery in the study area. It is also possible that feral fauna would benefit from the increased construction of roads and disturbance to native vegetation. However, the feral animal control strategy and the pest and weed management plan proposed to be implemented as part of the project would manage and monitor invasive species, ensuring that quality or integrity of this ecological community isn't substantially reduced.

Causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community, or

The project is unlikely to cause regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the Weeping Myall Woodlands ecological community. Accidental spills and leaks of drilling fluid, cement, hydrocarbons and other substances have the potential to impact this ecological community.

Provided adequate casing, bunding and erosion and sediment control protection is installed, accidental spills and leaks are unlikely to significantly affect surrounding vegetation including this ecological community.

Interfere with the recovery of an ecological community.

The project is unlikely to interfere substantially with the recovery of the Weeping Myall Woodlands ecological community. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this ecological community in the study area including its distribution, species diversity and abundance and possible or observed threats. Monitoring would ensure that proposed mitigation measures are substantially managing this ecological community and would trigger additional actions if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact the Weeping Myall Woodlands ecological community in the study area as only up to 0.10 ha of habitat critical to the survival of the community would be directly impacted and no additional habitat would be indirectly impacted.

Over 99% of the ecological community in the study area would not be directly or indirectly impacted and it is unlikely that the extent or condition would be substantially changed. The removal of this ecological community in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this ecological community are not considered likely to impact its long-term survival in the study area.

1.2 Flora: Vulnerable

Androcalva procumbens – Vulnerable

Androcalva procumbens (syn. *Commersonia procumbens* (as listed in TSC Act) and *Rulingia* procumbens) was not known from the study area prior to commencing survey work, however it had been recorded just south in Pilliga Nature Reserve (OEH 2016a). Several other pre-2010 records had been made to the south and west within 50 km of the study area boundary. The species was initially opportunistically located in the study area in early 2011 and population counts and random meanders in suitable habitat were made at that time. Targeted transect surveys were undertaken in spring 2012 and additional population counts made opportunistically in late 2013 and early 2014. All records are from the far south eastern corner of study area, where they were found predominantly along the edge of tracks and recently burnt areas. A total of 359 individuals were recorded within the study area and the total population estimate for the north-east Pilliga (incorporating the study area) is 792,668 individuals. ELA botanists also recorded *R. procumbens* at 37 sites (comprising seven sub-populations) to the south of the study area boundary.

Androcalva procumbens is endemic to NSW. Beyond the Pilliga area populations are known from north east of Narrabri, the Dubbo–Medooran–Gilgandra region, south of Cobar, and the upper Hunter Valley (OEH 2016a; TSSC 2008). The broader Pilliga region population of *R. procumbens* (including the study area occurrences) is regarded as significant on the basis of its considerable size, habitat quality and lack of population size data for other known sites in NSW.

The study area supports 69,940 ha of potential habitat for this species. Approximately 240,274 individuals have been estimated to occur in the study area, based on habitat modelling calculations (lower 95% confidence interval 90,799 individuals, upper 95% confidence interval 858,601 individuals). An upper limit of 3,716 individuals (1,404 – 13,265 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the *Androcalva procumbens* population. Over 98% of the total population in the study area would not be directly or indirectly impacted.

This species is often found in disturbed habitats, including along road edges and other cleared environments (TSSC 2008). This is supported by many of the records in the study area being along edges of tracks and in recently burnt areas. It is possible that the direct and indirect impacts in suitable habitat may trigger the germination of this species and may lead to an increased population size in the study area. The study area contains suitable habitat for *Androcalva procumbens* that is currently unoccupied by the species.

Reduce the area of occupancy of an important population

An upper limit of 3,716 individuals (1,404 – 13,265 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. These impacts would be contained within the existing population and are unlikely to significant reduce the area of occupancy for this species.

Fragment an existing important population into two or more populations

The project is unlikely to fragment the existing *Androcalva procumbens* population into two or more populations. The removal of up to 3,716 individuals (1,404 – 13,265 individuals with a 95% confidence interval) would occur by constructing either well pads or gathering system. The well pads would be a maximum of 1 ha, and rehabilitated as soon as possible after impact to 0.45 ha. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, and the prevalence of this species occurring along road edges, the additional patches are still considered to be linked as pollination and dispersal could still occur between patches.

Adversely affect habitat critical to the survival of a species

The project is likely to affect habitat critical to the survival of *Androcalva procumbens*.

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.55% of the number of individuals in the study area and available habitat would be directly or indirectly impacted which correlates to the occupied habitat in the study area.

Habitat for *Androcalva procumbens* is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this species.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (pollination, seed development, dispersal and germination).of the *Androcalva procumbens* population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals growing within proximity such that genetic diversity is maintained through pollination. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the germination of seedlings and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.55% of habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Androcalva procumbens has been recorded in the far south eastern corner of study area, predominantly along the edge of tracks and recently burnt areas. The study area would still maintain over 98% of habitat. Both the quality and availability of the maintained habitat would not be impacted on. The scale of the fragmentation would not inhibit the breeding cycle for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in *Androcalva procumbens* habitat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of *Androcalva procumbens*. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of *Androcalva procumbens*. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species in the study area including its distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact *Androcalva procumbens* in the study area.

Over 98% of the number of individuals in the study area would not be directly or indirectly impacted and it is unlikely that the breeding cycle would be disrupted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Bertya opponens (Coolabah Bertya) – Vulnerable

Bertya opponens is a slender multi- or single-stemmed shrub that grows to four metres. This species has a highly restricted geographic distribution in NSW, and is known only from a few scattered sites including Coolabah, south of Narrabri on the North West Slopes, Cobar and the North Coast (NSW Scientific Committee 2009). This species is known to occur in the north-east Pilliga Forest in Jacks Creek State Forest (ELA 2012), part of which is located within the study area.

When last assessed in 1999 the population on 'Nurrungal' consisted of 500-600 adult plants, whilst the population on 'Windera Station' is now believed to be extinct (NPWS 2002a). The population within Jacks Creek State Forest and adjoining private land is the most significant population of *Bertya opponens* in NSW and critical to the long term persistence of the species in the state. If the estimated 5,000,000 plants occurring in Jacks Creek State Forest is accurate, approximately 20% of the main population occurs within the study area. The species is known from numerous locations in central Queensland.

The habitats in which *B. opponens* is found include stony mallee ridges and cypress pine forest on red soils. The species is associated with a shrub layer of *Philotheca ciliata, Phebalium squamulosum* (Scaly Phebalium) and *Acacia* spp. and a sparse grassy groundcover (ELA 2012).

The area of occupied habitat in the study area is approximately 456 ha. Within this occupied habitat, this species occurs at an average density of 1,618 individuals per hectare. Approximately 956,861 individuals have been estimated to occur in the study area, based on habitat mapping calculations and supplementary extrapolation for sub-populations that are assumed to be present but have not yet been observed. An upper limit of 10,309 individuals would be removed or indirectly impacted which constitutes 1.08% of the number of individuals in the study area. An upper limit of 6.37 ha of occupied habitat in the study area would be directly or indirectly impacted which constitutes 1.40% of the occupied habitat in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the *Bertya opponens* population. Over 98% of the total population in the study area would not be directly or indirectly impacted.

This species is thought to require disturbance for germination, as the disturbance can stimulate the seed bank. Appropriate fire regimes and mechanical disturbance through road grading is thought to be the reason that seedlings are abundant in the Jacks Creek State Forest population. The lack of seedlings at two other populations aligns with the lack of appropriate disturbance cues at both sites. It is possible that the direct and indirect impacts in suitable habitat may trigger the germination of this species and may lead to an increased population size in the study area. The study area contains suitable habitat for *Bertya opponens* that is currently unoccupied by the species.

Reduce the area of occupancy of an important population

Up to 6.37 ha of occupied habitat in the study area would be directly or indirectly impacted as a result of the project. This equates to 1.40% of the occupied habitat in the study area. These impacts would be contained within the existing population and are unlikely to significant reduce the area of occupancy for this species.

Fragment an existing important population into two or more populations

The project is unlikely to fragment the existing *Bertya opponens* population into two or more populations. The removal of up to 10,309 individuals would occur by constructing either well pads or gathering system. The well pads would be a maximum of 1 ha, and rehabilitated as soon as possible after impact to 0.45 ha. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. This population would not be intersected by the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked as pollination and dispersal could still occur between patches.

Adversely affect habitat critical to the survival of a species

The project is likely to directly and indirectly impact habitat critical to the survival of *Bertya opponens*.

Habitat for *Bertya opponens* is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. No critical habitat is listed in the recovery plan for this species (NPWS 2002a).

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is considered necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.40% of habitat critical to the survival of this species in the study area would be directly or indirectly impacted.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (pollination, seed development, dispersal and germination).of the *Bertya opponens* population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals growing within proximity such that genetic diversity is maintained through pollination. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the germination of seedlings and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.40% of occupied habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Bertya opponens has been recorded in dense patches in the north-east of the study area. The study area would still maintain over 98% of occupied habitat in the study area. Both the quality and availability of the maintained habitat would not be impacted on. The scale of the fragmentation would not inhibit the breeding cycle for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in *Bertya opponens* habitat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of *Bertya opponens*. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of *Bertya opponens*. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species in the study area including its distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact *Bertya opponens* in the study area.

Over 98% of the number of individuals in the study area would not be directly or indirectly impacted and it is unlikely that the breeding cycle would be disrupted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Lepidium aschersonii (Spiny peppercress) – Vulnerable

Prior to commencing survey work for this assessment there were 29 records (from approximately 9 subpopulations) for the species in the study area (OEH 2016a). All of these records were concentrated within and around Brigalow Nature Reserve and Brigalow State Conservation Area. Although conditions were not favourable for detection of the species during fieldwork in the north western part of the study area in 2013 and 2014, 208 individuals (from four sub-populations) were recorded by ELA botanists. 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. These additional records have added considerably to the knowledge of the species in the study area.

Lepidium 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 study area.

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 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 (OEH 2016b), 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).

The species grows as a component of the ground flora on grey loamy clays(OEH 2016b). It is found on ridges of gilgai clays dominated by *Acacia harpophylla* (Brigalow), with *Rytidosperma* and/or *Austrostipa* spp. in the understorey. Vegetation structure varies from open to dense Brigalow, with a sparse grassy understorey and occasional heavy litter.

An upper limit of three individuals would be removed or indirectly impacted which constitutes 1.55% of the number of individuals known in the study area. Should surveys increase the known abundance of these species during the project, then the number of impacted individuals can increase but must stay below 1.55% of the population in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the *Lepidium aschersonii* population. The project would be restricted to removing a limit of 1.55% of the population in the study area which would not lead to a long-term decrease in the size of the population that occurs in the study area.

Reduce the area of occupancy of an important population

The project would be restricted to removing a limit of 1.55% of the population. These impacts would be contained within the existing population and are unlikely to significant reduce the area of occupancy for this species.

Fragment an existing important population into two or more populations

The project is unlikely to fragment the existing *Lepidium aschersonii* population into two or more populations. The removal of up to 1.55% of the population would occur by constructing either well pads or gathering system. The well pads would be a maximum of 1 ha, and rehabilitated as soon as possible after impact to 0.45 ha. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches of habitat are still considered to be linked as pollination and dispersal could still occur between patches.

Adversely affect habitat critical to the survival of a species

Habitat for *Lepidium aschersonii* is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. No critical habitat is listed in the recovery plan for this species (Carter 2010).

Using the definition for this assessment, all occupied habitat for this species in the study area is considered habitat critical to the survival of the species as it is necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.55% of the number of individuals in the study area would be directly or indirectly impacted which correlates to the occupied habitat in the study area.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (pollination, seed development, dispersal and germination).of the *Lepidium aschersonii* population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals growing within proximity such that genetic diversity is maintained through pollination. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the germination of seedlings and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.55% of the population in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Lepidium aschersonii has been recorded in the north-western portion of the study area. Over 98% of the population in the study area would be maintained in the study area with the project. Both the quality and availability of the maintained habitat would not be impacted on. The scale of the fragmentation would not inhibit the breeding cycle for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in *Lepidium aschersonii* habitat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of *Lepidium aschersonii*. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of *Lepidium aschersonii*. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species in the study area including its distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact *Lepidium aschersonii* in the study area.

Over 98% of the number of individuals in the study area would not be directly or indirectly impacted and it is unlikely that the breeding cycle would be disrupted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.3 Flora: Endangered

Lepidium monoplocoides (Winged Peppercress) – Endangered

Lepidium monoplocoides was not known from the study area prior to commencing survey work, however it was recorded from nearby in the Pilliga National Park and adjoining Pilliga State Conservation Area soon after (ELA 2012; Bell et al. 2012). During the course of vegetation sampling 258 individuals (from three subpopulations) were recorded within the study area towards the northern boundary, south west of Narrabri. The species is difficult to detect and given the dry conditions at the time when suitable habitat was surveyed, it is possible that the species is more frequent in the north western section of the study area than current records indicate.

Lepidium monoplocoides occurs in north western Victoria and South Australia, southern Queensland, and is widely distributed in semi-arid plains regions of NSW. 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. Although the population within the study area may not be large, it should be regarded as significant until further data clarifies the extent and size of populations in the greater Pilliga region.

Lepidium monoplocoides is known to occur on seasonally moist to waterlogged sites, on heavy fertile soils (OEH 2016b). The species is usually associated with open woodland dominated by *A. luehmannii* and/or eucalypts with a tussock grassy understorey. In the Pilliga National Park, this species has been found in Narrow-leaved Ironbark – White Cypress Pine - Buloke tall open forest, and was found to be associated with gilgais (ELA 2012). In the study area, it was found near roadsides and in run-on areas in Mugga Ironbark - White Cypress Pine - gum tall woodland.

An upper limit of four individuals would be removed or indirectly impacted which constitutes 1.55% of the number of individuals known in the study area. Should surveys increase the known abundance of these species during the project, then the number of impacted individuals can increase but must stay below 1.55% of the population in the study area.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the *Lepidium monoplocoides* population. The project would be restricted to removing a limit of 1.55% of the population in the study area which would not lead to a long-term decrease in the size of the population that occurs in the study area.

Reduce the area of occupancy of the species

The project would be restricted to removing a limit of 1.55% of the population. These impacts would be contained within the existing population and are unlikely to significant reduce the area of occupancy for this species.

Fragment an existing population into two or more populations

The project is unlikely to fragment the existing *Lepidium monoplocoides* population into two or more populations. The removal of up to 1.55% of the population would occur by constructing either well pads or gathering system. The well pads would be a maximum of 1 ha, and rehabilitated as soon as possible after impact to 0.45 ha. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches of habitat are still considered to be linked as pollination and dispersal could still occur between patches.

Adversely affect habitat critical to the survival of a species

Habitat for *Lepidium monoplocoides* is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. No critical habitat is listed in the recovery plan for this species (Mavromihalis 2010).

Using the definition for this assessment, all occupied habitat for this species in the study area is considered habitat critical to the survival of the species as it is necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.55% of the number of individuals in the study area would be directly or indirectly impacted which correlates to the occupied habitat in the study area.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (pollination, seed development, dispersal and germination).of the *Lepidium monoplocoides* population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals growing within proximity such that genetic diversity is maintained through pollination. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the germination of seedlings and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.55% of the population in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Lepidium monoplocoides has been recorded in the north-western portion of the study area. Over 98% of the population in the study area would be maintained in the study area with the project. Both the quality and availability of the maintained habitat would not be impacted on. The scale of the fragmentation would not inhibit the breeding cycle for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

The project is unlikely to result in establishment of invasive species in *Lepidium monoplocoides* habitat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of *Lepidium monoplocoides*. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of *Lepidium monoplocoides*. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species in the study area including its distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact *Lepidium monoplocoides* in the study area.

Over 98% of the number of individuals in the study area would not be directly or indirectly impacted and it is unlikely that the breeding cycle would be disrupted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

***Tylophora linearis* – Endangered**

Tylophora linearis had not been recorded from the study area prior to commencing survey work, however it had been recorded at three sites within approximately 50 km south and south west of the study area (OEH 2016a). The species was initially opportunistically located in the study area in 2011. Targeted transect surveys for the species were undertaken in 2011 and 2012, and additional records were made as part of other studies between 2012 and 2014. A total of 376 individuals were recorded, all within the southern half study area. On the basis of population data presented by the NSW Scientific Committee (NSW Scientific Committee 2008), this would be the largest population known in NSW. ELA botanists also recorded *T. linearis* at 30 sites (mostly comprising individual plants) to the west and south of the study area boundary. During survey work, plants were commonly observed to be clonal, with numerous stems arising within an radius of up to 5 m. These clonal masses were assumed to be individual plants, rather than each stem representing an individual plant, a view supported by NSW Scientific Committee (NSW Scientific Committee 2008). A greater understanding of the ecology of the species was gained through work in the Pilliga region, which revealed that although *T. linearis* occurs in a broad range of vegetation types in the area; it was most often found in areas heavily burnt by the 2007 wildfire, along track edges and in recently cut road drains.

In NSW *Tylophora linearis* is known from relatively few scattered populations in the western slopes division, from Temora in the south to near Yetman in the north (OEH 2016a). The cryptic nature of the species, and its preference for growing in areas of little agricultural value, suggest that it may be still present in numerous areas which are currently considered gaps for the species (NSW Scientific Committee 2008). The broader Pilliga region population of *T. linearis* (including the study area occurrences) is regarded as significant on the basis of its estimated large size and habitat quality. The species also occurs in the Glenmorgan district in southern Queensland, where it is very rare and poorly known.

The study area supports 69,940 ha of potential habitat for this species. Approximately 33,154 individuals have been estimated to occur in the study area, based on habitat modelling calculations (lower 95% confidence interval 25,739 individuals, upper 95% confidence interval 43,712 individuals). An upper limit of 513 individuals (398 – 676 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. The modelling is based on the direct and indirect impact of 1,081.78 ha of habitat which constitutes 1.55% of habitat in the study area.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the *Tylophora linearis* population. Over 98% of the total population in the study area would not be directly or indirectly impacted.

This species is often found in disturbed habitats in the study area, including areas heavily burnt by the 2007 wildfire, along track edges and in recently cut road drains. It is possible that the direct and indirect impacts in suitable habitat may trigger the germination of this species and may lead to an increased population size in the study area. The study area contains suitable habitat for *Tylophora linearis* that is currently unoccupied by the species.

Reduce the area of occupancy of the species

An upper limit of 513 individuals (398 – 676 individuals with a 95% confidence interval) would be removed or indirectly impacted which constitutes 1.55% of the number of individuals in the study area. These impacts would be contained within the existing population and are unlikely to significant reduce the area of occupancy for this species.

Fragment an existing population into two or more populations

The project is unlikely to fragment the existing *Tylophora linearis* population into two or more populations. The removal of up to 513 individuals (398 – 676 individuals with a 95% confidence interval) would occur by constructing either well pads or gathering system. The well pads would be a maximum of 1 ha, and rehabilitated as soon as possible after impact to 0.45 ha. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are still considered to be linked as pollination and dispersal could still occur between patches.

Adversely affect habitat critical to the survival of a species

The project is likely to affect habitat critical to the survival of *Tylophora linearis*.

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.55% of the number of individuals in the study area and 1.55% of available habitat would be directly or indirectly impacted which correlates to the occupied habitat in the study area.

Habitat for *Tylophora linearis* is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this species.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (pollination, seed development, dispersal and germination).of the *Tylophora linearis* population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals growing within proximity such that genetic diversity is maintained through pollination. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the germination of seedlings and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.55% of habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Tylophora linearis has been recorded in the southern half study area. The study area would still maintain over 98% of habitat in the study area. Both the quality and availability of the maintained habitat would not be impacted on. The scale of the fragmentation would not inhibit the breeding cycle for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

The project is unlikely to result in establishment of invasive species in *Tylophora linearis* habitat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of *Tylophora linearis*. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of *Tylophora linearis*. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species in the study area including its distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact *Tylophora linearis* in the study area.

Over 98% of the number of individuals in the study area would not be directly or indirectly impacted and it is unlikely that the breeding cycle would be disrupted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that pollination and dispersal could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.4 Birds: Vulnerable

Grantiella picta (Painted Honeyeater) – Vulnerable

The Painted Honeyeater occurs in the eastern half of Australia, from the eastern Northern Territory, through Queensland, New South Wales and Victoria to south-eastern South Australia (DSE 2003). It occurs predominantly on the inland side of the Great Dividing Range but avoids arid areas (Blakers et al. 1984). It is a nomadic species and occurs at low densities throughout its range. The greatest concentrations of the bird (and almost all breeding), occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. During the winter it is more likely to be found in the north of its distribution, in the semi-arid woodlands of inland and northern Australia (OEH 2016b). The species has been observed at two locations in the west of the study area, near Bundock Creek within Pilliga East State Forest. It was also recorded in the east of the study area near a tributary to Spring Creek and just outside the eastern edge of the study area. Previous records of the species are concentrated in the north-west of the study area, including Yarrie Lake, in and around Brigalow Nature Reserve and Brigalow State Conservation Area (OEH 2016a).

The Painted Honeyeater is a specialist feeder on mistletoe berries, particularly those of the genus *Amyema* growing on woodland eucalypts and acacias (DSE 2003). Breeding individuals depend primarily on *A. cambagei* and *A. quandang* (Garnett et al. 2011), both of which grow in the study area. It inhabits Boree, Brigalow and Box-Gum Woodlands and Box-Ironbark Forests (OEH 2016b). Within the eastern Pilliga, it is known to utilise riparian woodland and shrub-grass woodland habitats. Other predicted habitat for the species in the study area includes closed forest, water bodies, grassy woodland, heathy woodland and shrubby woodland.

Due to the species dispersing nature, all individuals are considered to consist of one subpopulation (Garnett et al. 2011). The study area supports key breeding resources and is within the geographic range that supports the greatest concentrations. Hence the study area is considered to be an important component for the population and therefore support an important population.

Within the study area, approximately 69,632 ha of habitat has been mapped which provides 69,632 ha of foraging habitat and 69,632 ha of breeding habitat. Within the study region, approximately 308,870 ha of habitat has been mapped which provides 308,870 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27%% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.52% of foraging habitat and 1.53% of breeding habitat in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the Painted Honeyeater population. The study area supports both breeding and foraging and is within the geographic range that supports a relatively high abundance of the species. Key breeding resources (of *Amyema* spp.) would be avoided where possible using the Field Development Protocol. Over 98% of foraging and breeding habitat in the study area would not be directly or indirectly impacted. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region. It is considered that this habitat would still support breeding and foraging for this population in the study area.

The removal and reduction in habitat quality in less than 2% of the habitat is not likely to restrict breeding or foraging for this species in the study area. Due to the minimisation of impacts to key habitat features and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to cause a long-term decrease in the population.

Reduce the area of occupancy of an important population

The project is likely to reduce the area of occupancy of the Painted Honeyeater population. It is not possible to know the exact area of occupancy for this species in the study area as all known breeding and foraging sites have not been mapped. However, the direct impact on foraging and breeding habitat in the study area is likely to result in the removal of a portion of occupied habitat. Up to 1,060 ha of foraging and breeding habitat would be removed or indirectly impacted which constitutes less than 2% of the available foraging and breeding habitat in the study area. It is possible that a portion of this habitat would be occupied by the species, either for forging and/or breeding.

Fragment an existing important population into two or more populations

The project is unlikely to fragment an existing population of Painted Honeyeater into two or more populations. This species is known to occur in the study area, with an existing population considered to use the study area for foraging and breeding.

Up to 885.00 ha of foraging and breeding habitat would be removed which constitutes less than 2% of the available foraging and breeding habitat in the study area. Removal of this habitat would increase the fragmentation in the study area and it is likely that additional patches of habitat would be formed.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the species would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is likely to affect habitat critical to the survival of Painted Honeyeater.

Habitat for Painted Honeyeater is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for foraging, breeding, roosting and dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.53% of the habitat in the study area would be directly or indirectly impacted of which a portion would be occupied and providing habitat critical to the survival of this species.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (mating, egg laying, egg hatching, chic rearing, fledging) of the Painted Honeyeater population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species’ lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals to occur within proximity such that genetic diversity is maintained through mating. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the birth of young and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.53% of habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Painted Honeyeater has been recorded in the study area and is considered to use habitat in the study area for foraging and breeding. Over 98% of foraging and breeding habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging or breeding habitat of Painted Honeyeater. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Painted Honeyeater. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Painted Honeyeater. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Painted Honeyeater in the study area.

Painted Honeyeater has been recorded in the study area is considered to use habitat in the study area for foraging and breeding. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Polytelis swainsonii (Superb Parrot) – Vulnerable

The Superb Parrot is found in NSW and northern Victoria, where it occurs on the inland slopes of the Great Divide and on adjacent plains, especially along the major river-systems. On occasion, vagrants have been recorded in southern Queensland. The core breeding area is located on the South-western Slopes of NSW. Birds breeding in this region are mainly absent during winter, when they migrate north to the region of the upper Namoi and Gwydir Rivers. There are scattered records of Superb Parrot in the Pilliga, mainly fringing the vegetated areas in the north, south and west (OEH 2016a). The other main breeding sites are in the Riverina along the corridors of the Murray, Edward and Murrumbidgee Rivers where birds are present all year round (OEH 2016b). The species is not known to breed in the Pilliga. There is the potential for this species to occur in the study area during the non-breeding season (winter).

The Superb Parrot inhabits box-gum woodland, Box-Cypress-pine and Boree Woodlands and River Red Gum Forest. The populations that migrate to the Namoi region in winter forage and roost in forests and woodlands dominated by *Callitris glaucophylla* (White Cypress Pine) and Box-gum. Previous sightings of Superb Parrot in the Pilliga Forest have been associated with drainage lines, foraging in Eucalypt canopy and grassland and flying through the landscape (OEH 2016a). The Superb Parrot forages on the ground, in understorey shrubs and in the forest canopy, feeding on the seeds of native and exotic grasses, cereal crops, spilt grain, acacias seeds, eucalypt flowers and fruits, mistletoe berries and lerps (Christie 2004; Frith & Calaby 1953; Webster 1988; Webster & Ahern 1992). Water bodies, riparian woodland and shrub-grass woodland are the habitat types predicted to be potential habitat for the species within the study area.

Within the study area, approximately 35,574 ha of habitat has been mapped which provides 35,574 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 195,490 ha of habitat has been mapped which provides 195,490 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 416.80 ha of foraging habitat would be directly impacted which equates to 1.17% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 82.02 ha of foraging habitat which would combine to impact a total of 1.40% of foraging habitat in the study area.

No Superb Parrots have been recorded in the study area. An important population is not likely to be supported by habitat in the study area as the study area does not provide key breeding habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The study area is not likely to support an important population.

Reduce the area of occupancy of an important population

The study area is not likely to support an important population.

Fragment an existing important population into two or more populations

The study area is not likely to support an important population.

Adversely affect habitat critical to the survival of a species

Habitat for Superb Parrot is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.

The recovery plan (Baker-Gabb 2011) describes the breeding and foraging habitat that is critical to the survival of this species. No breeding habitat for this species occurs in the study area. The foraging habitat in the study region critical to the survival of this species is described as *'eucalypt-pine woodlands on the plains of the west-central and north-central New South Wales'*. This potential foraging habitat mapped in the study area aligns with this definition and hence up to 35,574 ha of foraging habitat critical to the survival of the species is present in the study area. Up to 416.80 ha of this foraging habitat would be directly impacted which equates to 1.17% of foraging habitat directly impacted in the study area.

Disrupt the breeding cycle of an important population

The study area is not likely to support an important population.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Superb Parrot has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of potential foraging habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of Superb Parrot. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Superb Parrot. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Superb Parrot. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Superb Parrot in the study area, despite it adversely affecting habitat critical to the survival of the species.

Superb Parrot has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.5 Birds: Endangered

Wetland or aquatic birds

Botaurus poiciloptilus (Australasian Bittern) and *Rostratula australis* (Australian Painted Snipe) are considered in this assessment.

Botaurus poiciloptilus (Australasian Bittern) – Endangered

The Australasian Bittern occurs from south-east Queensland to south-east South Australia, Tasmania and the south-west of Western Australia (Marchant & Higgins 1990). They are widespread but uncommon across NSW, found over much of the state except for the far north-west. There is the potential for this species to occur within the study area as they are known to occur in the Pilliga and Pilliga Outwash sub-regions of the Namoi catchment (OEH 2016b). There are records from the 1970s in the Pilliga Nature Reserve and to the north-west of the study area (OEH 2016a; DotE 2014a).

The species favours permanent and seasonal freshwater habitats, particularly those dominated by sedges, rushes or reeds (e.g. *Phragmites, Cyperus, Eleocharis, Juncus, Typha, Baumea, Bolboschoenus*) or cutting grass (*Gahnia*) growing on a muddy or peaty substrate (Marchant & Higgins 1990). In inland Australia, this may include freshwater wetlands, tussocky wet paddocks, drains or rice fields((OEH 2016b). Water bodies are the predicted habitat for the species within the study area. The Australasian Bittern forages in still, shallow water up to 0.3 m deep with medium to low vegetation density. Available data indicate that it breeds in relatively deep, densely-vegetated freshwater swamps and pools, building its nests in deep cover over shallow water (Marchant & Higgins 1990).

No foraging habitat in the study area would be directly or indirectly impacted. There is no breeding habitat mapped in the study area.

Rostratula australis (Australian Painted Snipe) – Endangered and Marine

The Australian Painted Snipe has been recorded in wetland habitats in all states of Australia. It is most common in eastern Australia, where it has been recorded at scattered locations throughout much of Queensland, NSW, Victoria and south-eastern South Australia. It has been recorded less frequently at a smaller number of more scattered locations farther west in South Australia, the Northern Territory and Western Australia. The species has mainly been recorded breeding in the Murray-Darling region, but has also been recorded in south-east Queensland, eastern NSW, south-east South Australia and the Mt Lofty Ranges (DotE 2016b). Records of this species occur south in the Pilliga Nature Reserve, east in the Liverpool Plains and north near Narrabri and Pilliga (OEH 2016a). There are no records in the study area.

The Australian Painted Snipe is found in shallow terrestrial freshwater wetlands, preferring the fringes of swamps, dams and nearby marshy areas, where there is a cover of grasses, lignum, low scrub or open timber (OEH 2016b). Water bodies are the predicted habitat for the species within the study area. It roosts during the day in dense vegetation, and forages nocturnally on mud-flats and in shallow water, feeding on worms, molluscs, insects and some plant-matter (OEH 2016b). It generally nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds. Most nests recorded have been located on small islands in freshwater wetlands, but nesting may also occur near swamps, and flooded areas of grazing land or other vegetation (Marchant & Higgins 1993).

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the Australian Bittern or Australian Painted Snipe populations. Both species have not been recorded in the study area. Potential aquatic habitat in the study area would not be directly or indirectly impacted by the project.

Reduce the area of occupancy of the species

The project is unlikely to reduce the area of occupancy of the Australian Bittern or Australian Painted Snipe. These species are not known to occupy the study area and hence no habitat in the study area is considered an area of occupancy for these species.

Fragment an existing population into two or more populations

The project is unlikely to fragment an existing population of Australian Bittern or Australian Painted Snipe into two or more populations. These species are not known to occur in the study area, with an existing population considered to potentially use the study area for infrequent foraging. The Australian Painted Snipe has potential to use the study area for breeding.

No foraging or breeding habitat would be directly or indirectly impacted. Due to the nature of the proposed infrastructure, it is unlikely that movement between aquatic habitats in the study area would be impeded.

Adversely affect habitat critical to the survival of a species

No foraging or breeding habitat for Australian Bittern or Australian Painted Snipe would be directly or indirectly impacted by the project and hence it is unlikely that habitat critical to the survival of these species would be adversely affected.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (mating, egg laying, egg hatching, chic rearing, fledging) of a, Australian Bittern or Australian Painted Snipe population. The study area does not support breeding for Australian Bittern and hence impacts to the study area would not impact its breeding cycle. No breeding habitat for the Australian Painted Snipe would be directly or indirectly impacted in the study area.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline. No foraging or breeding habitat for Australian Bittern or Australian Painted Snipe would be directly or indirectly impacted by the project.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

The project is unlikely to result in establishment of invasive species in potential habitat of Australian Bittern or Australian Painted Snipe. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to the habitat of these species (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for these species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Australian Bittern or Australian Painted Snipe. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support habitat for these species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Australian Bittern or Australian Painted Snipe. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of these species and their habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Australian Bittern or Australian Painted Snipe in the study area.

No foraging or breeding habitat for Australian Bittern or Australian Painted Snipe would be directly or indirectly impacted by the project. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on these species are not considered likely to impact its long-term survival in the study area.

1.6 Birds: Critically Endangered

Anthochaera phrygia (Regent Honeyeater) – Critically Endangered

The Regent Honeyeater has an extremely patchy distribution across the inland slopes of south-east Australia between north-eastern Victoria and south-eastern Queensland (OEH 2016b). Birds are also found in drier coastal woodlands and forests in some years. In NSW, most records are from the Great Dividing Range, mainly on the North-West Plains, North-West and South-West Slopes, Northern Tablelands, Central Tablelands and Southern Tablelands regions; as well as the Central Coast and Hunter Valley regions. Regent Honeyeaters have been recorded sporadically in the Pilliga (in 1991, 1992, 1997 and 2003; OEH 2014a). Their distribution in the Pilliga may fluctuate based on fluctuations of eucalypt flowering, including *E. albens* beyond the Pilliga. Minor and sporadic breeding occurs in Warrumbungle National Park, Pilliga Nature Reserve and Mudgee-Wollar region (Garnett et al. 2011; OEH 2016b).

Regent Honeyeaters are associated with temperate eucalypt woodland and open forest including forest edges, wooded farmland and urban areas with mature eucalypts, and riparian forests of *Casuarina cunninghamiana* (River Oak) (Garnett 1993). The Regent Honeyeater primarily feeds on nectar from box and ironbark eucalypts and occasionally from banksias and mistletoes. As such it is reliant on locally abundant nectar sources with different flowering times to provide reliable supply of nectar (Garnett & Crowley 2000). Insects make up about 15% of the species' total diet, and lerp and honeydew are important when nectar is scarce (OEH 2016b).

The Warrumbungles, Pilliga Nature Reserve and adjoining habitat to the south of the development site has been mapped as 'other breeding areas' that support the key breeding area of Bundarra-Barraba in the National Recovery Plan (DotE 2016a). A coarse-scale map provided in the National Recovery Plan was digitised and overlayed with the development site boundary. The 'other breeding area' mapped in the Pilliga overlays with approximately 2,755 ha (2.90%) of the development site in the south-eastern corner. The vegetation communities mapped in this area are predominantly PCTs 404, 405 and 406 which are shrubby and heathy woodlands. They are not associated with drainage lines and don't support local preferred flowering Eucalypt species. At a site-scale, this habitat is not considered preferred breeding habitat for Regent Honeyeater.

The species is considered to have the potential to occur in the study area. Previous sightings of Regent Honeyeaters in the Pilliga Forest have been largely associated with drainage lines (OEH 2016a). They are mostly observed in Box – Ironbark Eucalypt woodland and dry sclerophyll forest associations, and are known to prefer more fertile habitats along drainage lines, in broad river valleys and foothills. Eucalypts that reliably produce large amounts of nectar occurring in the Pilliga are *E. sideroxylon*, *E. melliodora* (Yellow Box) and *E. albens* (White Box). In particular, areas of *E. sideroxylon* X *melliodora* hybrid and *E. sideroxylon* occur in the study area. Other eucalypt associations that occur in the Pilliga are *E. blakelyi* (Blakely's Red Gum), *E. melanophloia* (Silver-leaved Ironbark), *E. crebra* (Narrow-leaved Ironbark) and *Angophora floribunda* (Rough-barked Apple). Loss of habitat also forces Regent Honeyeaters to use less productive habitat.

Within the study area, approximately 57,579 ha of potential habitat has been mapped which provides 57,579 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 246,370 ha of habitat has been mapped which provides 246,370 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 796.80 ha of potential foraging habitat would be directly impacted which equates to 1.38% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 157.48 ha of habitat which would combine to impact a total of 1.66% of foraging habitat in the study area.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the Regent Honeyeater population. The species has not been recorded in the study area but has been recorded infrequently in habitat that is connected to the study area. The study area does not support breeding and is not considered a reliable foraging resource. Use of the foraging habitat in the study area would be sporadic and during times when more favourable foraging habitat is not available or when flowering in the study area is more profuse.

Reduce the area of occupancy of the species

The project is unlikely to reduce the area of occupancy of the Regent Honeyeater. This species is not known to occupy the study area and hence no habitat in the study area is considered an area of occupancy for this species.

Fragment an existing population into two or more populations

The project is unlikely to fragment an existing population of Regent Honeyeater into two or more populations. This species is not known to occur in the study area, with an existing population considered to potentially use the study area for infrequent foraging.

Up to 796.80 ha of foraging habitat which constitutes approximately 1.38% of foraging habitat in the study area would be removed and would increase the fragmentation in the study area. It is likely that additional patches of habitat would be formed.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the species would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is unlikely to adversely affect habitat critical to the survival of the Regent Honeyeater. Habitat for Regent Honeyeater is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.

The national recovery plan (DotE 2016a) identifies habitat critical to the survival of the Regent Honeyeater as:

1. Any breeding or foraging habitat in areas where the species is likely to occur (as defined by the distribution map provided); and
2. Any newly discovered breeding or foraging locations.

97.1% of the study area is mapped as area where the species may occur and is not considered to support breeding. No individuals of Regent Honeyeater have been recorded within the study area so is not a known foraging or breeding location. The south-eastern corner of the study area which overlaps with the Pilliga ‘other breeding’ area is not considered accurate at a site-scale as described above. Hence, the habitat in the study area is not critical to the survival of the Regent Honeyeater according to the national recovery plan definition.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (mating, egg laying, egg hatching, chic rearing, fledging) of a Regent Honeyeater population. The study area does not support breeding for this species and hence impacts to the study area would not impact the breeding cycle.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Regent Honeyeater has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of potential foraging habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species’ habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of Regent Honeyeater. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Regent Honeyeater. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Regent Honeyeater. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Regent Honeyeater in the study area.

Regent Honeyeater has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Lathamus discolor (Swift Parrot) – Critically Endangered and Marine

The Swift Parrot is endemic to south-eastern Australia. It breeds in Tasmania during spring and summer, migrating in the autumn and winter months to the box-ironbark forests and woodlands of south-eastern mainland Australia, from Victoria and the eastern parts of South Australia to south-east Queensland. In NSW, the species mostly occurs on the coast and south west slopes (OEH 2014b).

There are no records of Swift Parrot in the Pilliga (OEH 2016a); however, it has the potential to use habitat in the Pilliga occasionally for foraging during the winter, and has been recorded in the Namoi catchment area (OEH 2016b). Whilst overwintering on the mainland, Swift Parrots are semi-nomadic, foraging in areas where eucalypts are flowering profusely or where there are abundant psyllid infestations as they feed extensively on nectar and lerps during the non-breeding season (DotE 2016b).

Swift Parrots are known to prefer *Eucalyptus sideroxylon* (Mugga Ironbark) and box-ironbark woodland for foraging, actively selecting medium to large trees. Sightings are often correlated with drainage lines (DotE 2016b). Although they exhibit high site fidelity, droughts and low food abundance in preferred sites will cause them to use other areas of critical food resource (box-ironbark habitat in drainage lines is thought to act as a critical food resource during these times (DotE 2016b). Predicted habitat for the species within the study region includes water bodies, grassy woodland, heath, heathy woodland, riparian woodland and shrub-grass woodland.

Within the study area, approximately 57,579 ha of habitat has been mapped which provides 57,579 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 246,370 ha of habitat has been mapped which provides 246,370 ha of foraging habitat and 0 ha of breeding habitat. An upper limit of 796.80 ha of foraging habitat would be directly impacted which equates to 1.38% of foraging habitat in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 157.48 ha of foraging habitat which would combine to impact a total of 1.66% of foraging habitat in the study area.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the Swift Parrot population. The species has not been recorded in the study area but has been recorded in habitat that is connected to the study area. The study area does not support breeding and is not considered a reliable foraging resource. Use of the foraging habitat in the study area would be sporadic and during times when more favourable foraging habitat is not available or when flowering in the study area is more profuse.

Reduce the area of occupancy of the species

The project is unlikely to reduce the area of occupancy of the Swift Parrot. This species is not known to occupy the study area and hence no habitat in the study area is considered an area of occupancy for this species.

Fragment an existing population into two or more populations

The project is unlikely to fragment an existing population of Swift Parrot into two or more populations. This species is not known to occur in the study area, with an existing population considered to potentially use the study area for infrequent foraging.

Up to 796.80 ha of foraging habitat which constitutes approximately 1.38% of foraging habitat in the study area would be removed and would increase the fragmentation in the study area. It is likely that additional patches of habitat would be formed.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the species would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is unlikely to adversely affect habitat critical to the survival of the Swift Parrot. Habitat for Swift Parrot is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. The recovery plan (Swift Parrot Recovery Team 2011) describes habitat that is critical to the survival of this species as those areas of priority habitat for which the species has a level of site fidelity or possess phonological characteristics likely to be of importance to the Swift Parrot, or are otherwise identified by the recovery team. The study area has not been listed as a priority site and is not known as an area with site fidelity for this species. The foraging habitat mapped in the study area is not considered to have characteristics likely to be of importance to the Swift Parrot such that it is critical it the survival of the species.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (mating, egg laying, egg hatching, chic rearing, fledging) of a Swift Parrot population. The study area does not support breeding for this species and hence impacts to the study area would not impact the breeding cycle.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Swift Parrot has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of potential foraging habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of Swift Parrot. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Swift Parrot. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Swift Parrot. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Swift Parrot in the study area.

Swift Parrot has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.7 Mammals: Vulnerable

Chalinolobus dwyeri (Large-eared Pied Bat) – Vulnerable

The distribution of the Large-eared Pied Bat is poorly known. Records exist from Rockhampton in Queensland south to Ulladulla in NSW. Much of the known range of the species is within NSW, although it is uncommon with a very patchy distribution. Available records suggest that the largest concentrations of populations occur in the sandstone escarpments of the Sydney basin and the north-west slopes (Coolah Tops, Mt Kaputar, Warrumbungle National Park and Pilliga Nature Reserve; DoE 2014).

The Large-eared Pied Bat has been recorded in a variety of habitats, including wet and dry sclerophyll forests, cypress pine dominated forest, woodland, sub-alpine woodland, edges of rainforests and sandstone outcrop country (DotE 2016b). This species roosts in caves, rock overhangs and disused mine shafts and as such is usually associated with rock outcrops and cliff faces (Churchill 2008). It also possibly roosts in the hollows of trees (Duncan et al. 1999). The species is thought to require roosting habitat that is adjacent to higher fertility sites, particularly box gum woodlands or river corridors, which are used for foraging. In the study area, the Large-eared Pied Bat is predicted to utilise grassy, heathy, shrubby, riparian and shrub-grass woodland habitat.

The number of known breeding sites is limited. No maternity roosts have been recorded in the study area. A maternity roost has been observed in a sandstone cave near Coonabarabran, NSW (Pennay 2008), and another nearby in the Pilliga sandstone (M. Pennay *pers. comm.* 2010 cited in DERM 2011). Small groups of females and young bats have been observed in the Pilliga Scrub (DERM 2011). Young have also been noted in a small group of females in a disused gold mine near Barraba, NSW (P. Spark *pers. comm.* 2011 cited in DERM 2011).

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 0 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and an unknown amount of breeding habitat. An upper limit of 885.00 ha of foraging habitat would be directly impacted which equates to 1.27% of foraging habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of foraging habitat would be indirectly which would combine to impact a total of 1.53% foraging habitat in the study area.

The Large-eared Pied Bat was not confidently recorded in the study area but is considered to potentially occur based on habitat presence and information obtained from the data and literature review. An important population is not likely to be supported by habitat in the study area as the study area does not provide key breeding habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The study area is not likely to support an important population.

Reduce the area of occupancy of an important population

The study area is not likely to support an important population.

Fragment an existing important population into two or more populations

The study area is not likely to support an important population.

Adversely affect habitat critical to the survival of a species

The project is unlikely to adversely affect habitat critical to the survival of the Large-eared Pied Bat. Habitat for Large-eared Pied Bat is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. The recovery plan (DERM 2011) describes habitat that is critical to the survival of this species; as areas with diurnal roosts for shelter. It is likely that habitat critical to the survival of this species includes roosting habitat in sandstone cliffs or rocky terrain in close proximity to foraging habitat in fertile wooded valleys. The study area does not support this type of habitat.

Disrupt the breeding cycle of an important population

The study area is not likely to support an important population.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Large-eared Pied Bat has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of potential foraging habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of Large-eared Pied Bat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Large-eared Pied Bat. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Large-eared Pied Bat. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Large-eared Pied Bat in the study area.

Large-eared Pied Bat has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging resource. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

***Nyctophilus corbeni* (South-eastern Long-eared Bat - South-eastern form) – Vulnerable**

The distribution of the South-eastern Long-eared Bat coincides approximately with the Murray Darling Basin with the Pilliga Scrub region being the distinct stronghold for this species (OEH 2016b). Eight South-eastern Long-eared Bats were recorded at six sites in the study area during surveys for this assessment. The literature review obtained an additional 20 South-eastern Long-eared Bat records from eight sites in the study area. Previously, records for the South-eastern Long-eared Bat were only from the forested portion of the study area. The record from closed forest in the Brigalow Nature Reserve from this assessment is the first record in the northern portion of the study area.

The South-eastern Long-eared Bat inhabits a range vegetation types including mallee, buloke, brigalow, belah and box eucalypt-dominated communities. However, it is more common in the box, ironbark, and cypress pine woodlands that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland (OEH 2016b). In the study area, it is known to occur in closed forest, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitats, and is also predicted to utilise grassy woodland habitats. The species roosts in tree hollows, crevices and under loose bark (DotE 2016b).

All field survey records of South-eastern Long-eared Bat are from individuals caught in harp traps. Echolocation calls from this species cannot be differentiated from other species of the same genus (*Nyctophilus*). As there are more than one species from the *Nyctophilus* genus that occur in the study area, no conclusions from the echolocation data can be made in reference to the South-eastern Long-eared Bat.

Within the study area, approximately 69,532 ha of habitat has been mapped which provides 69,532 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 302,437 ha of habitat has been mapped which provides 302,437 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 885.00 ha of habitat would be directly impacted (885.00 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.27% of both foraging and breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 175.41 ha of habitat (175.41 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.53% of both foraging and breeding habitat in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the South-eastern Long-eared Bat population. The study area supports both breeding and foraging and is considered part of a stronghold for the species. Over 98% of foraging and breeding habitat in the study area would not be directly or indirectly impacted. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region. It is considered that this habitat would still support breeding and foraging for this population in the study area.

The removal and reduction in habitat quality in less than 2% of the habitat is not likely to restrict breeding or foraging for this species in the study area. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to cause a long-term decrease in the population.

Reduce the area of occupancy of an important population

The project is likely to reduce the area of occupancy of the South-eastern Long-eared Bat population. It is not possible to know the exact area of occupancy for this species in the study area as all known roosting and foraging sites have not been mapped. However, the direct impact on foraging and breeding habitat in the study area is likely to result in the removal of a portion of occupied habitat. Up to 1,060 ha of foraging and breeding habitat would be removed or indirectly impacted which constitutes less than 2% of the available foraging and breeding habitat in the study area. It is possible that a portion of this habitat would be occupied by the species, either for forging and/or breeding.

Fragment an existing important population into two or more populations

The project is unlikely to fragment an existing population of South-eastern Long-eared Bat into two or more populations. This species is known to occur in the study area, with an existing population considered to use the study area for foraging and breeding.

Up to 885.00 ha of foraging and breeding habitat would be removed which constitutes less than 2% of the available foraging and breeding habitat in the study area. Removal of this habitat would increase the fragmentation in the study area and it is likely that additional patches of habitat would be formed.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Due to the scale of the proposed infrastructure, the additional patches are not considered ‘isolated’ as the species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the species would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is likely to affect habitat critical to the survival of South-eastern Long-eared Bat.

Habitat for South-eastern Long-eared Bat is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this species.

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for foraging, breeding, roosting and dispersal and supports the genetic diversity and long-term evolutionary development of the species. However, only up to 1.53% of the habitat in the study area would be directly or indirectly impacted of which a portion would be occupied and providing habitat critical to the survival of this species.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (mating, pregnancy, birth, lactating and rearing and dispersal) of the South-eastern Long-eared Bat population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals to occur within proximity such that genetic diversity is maintained through mating. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the birth of young and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.53% of habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

South-eastern Long-eared Bat has been recorded in the study area and is considered to use habitat in the study area for foraging and breeding. Over 98% of foraging and breeding habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging or breeding habitat of South-eastern Long-eared Bat. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of South-eastern Long-eared Bat. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging and breeding habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of South-eastern Long-eared Bat. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact South-eastern Long-eared Bat in the study area.

South-eastern Long-eared Bat has been recorded in the study area is considered to use habitat in the study area for foraging and breeding. Over 98% of the potential foraging habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Phascolarctos cinereus (Koala) – Vulnerable

The Koala has a fragmented distribution throughout eastern Australia from north-east Queensland to the Eyre Peninsula in South Australia. In NSW, it mainly occurs on the central and north coasts with some populations occurring west of the Great Dividing Range. Koalas are also known from several sites on the southern tablelands (OEH 2016b).

Koalas have been previously recorded throughout the Pilliga and surrounding areas. A large population is known to occur in the Liverpool Plains near Gunnedah and records continue through to the west of the Pilliga. Koalas have been recorded in the central and western regions of the Pilliga, and differing reports indicate uncommon to common presence in the east (Kavanagh & Barrott 2001). There are historic records of Koala in the study area, mostly centred in forested habitat west of the Newell Highway. The most recent record is from 2004.

The distribution and population size of Koalas in the Pilliga has varied, with population size believed to have dropped sharply between 1930 and 1980 due to hunting, predation by the European Red Fox, widespread ringbarking of eucalypts, and wildfire. Koala numbers were thought to have increased since the 1980s (Kavanagh & Barrott 2001) following the termination of hunting and ringbarking. However, drought and recent major wildfires (100,000 ha burnt in 2007 in the eastern Pilliga and 100,000 ha burnt in Warrumbungles in 2013) have impacted large areas of potential Koala habitat. Recent surveys for Koala in the Pilliga have found very low numbers in areas previously known to support resident populations (Niche Environment and Heritage 2014). All Koalas were located along Baradine Creek and Etoo Creek and their tributaries, west and southwest of the study area.

Koalas are associated with both wet and dry Eucalypt forest and woodland with a canopy cover of approximately 10 – 70% (Reed et al. 1990), that contains acceptable eucalypt food trees. *Eucalyptus camaldulensis*, a primary Koala food tree species as defined in the Approved Koala recovery plan (DECC 2008) and listed under the State Environmental Planning Policy 44, occurs in the study area. Secondary food trees recorded in the study area include *E. albens*, *E. blakelyi, E. chloroclada, E. conica*, *E. dealbata* (Tumbledown Gum), *E. dwyeri* (Dwyer's red gum), *E. macrocarpa*, *E. melliodora*, *E. pilligaensis* and *E. populnea*. *Eucalyptus macrorhyncha* (Red Stringybark), a listed supplementary food tree, is also present within the study area. *Callitris glaucophylla* is common, and is listed as a tree species used for daytime shelter.

Within the study area, approximately 80,398 ha of potential habitat has been mapped which provides up to 32,996 ha of foraging and breeding habitat and 80,398 ha of dispersal habitat. Within the study region, approximately 331,510 ha of potential habitat has been mapped which provides 100,081 ha of foraging and breeding habitat and 331,510 ha of dispersal habitat. An upper limit of 988.80 ha of potential habitat would be directly impacted (449.80 ha of potential foraging/breeding habitat and 988.80 ha of dispersal habitat) which equates to 1.36% of potential foraging/breeding habitat and 1.23% of dispersal habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (89.36 ha of potential foraging/breeding habitat and 181.11 ha of dispersal habitat) which would combine to impact a total of 1.63% of potential foraging/breeding habitat and 1.46% of dispersal habitat in the study area.

There are no recent sightings of Koala in the study area. An important population is not likely to be supported by habitat in the study area as the study area does not provide key breeding habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide core Koala habitat. During times of low population numbers, the Koala population is known to persist in areas outside of the study area along Etoo Creek and Baradine Creek. The habitat in the study area is considered to provide potential foraging, breeding and dispersal habitat for Koala during preferable environmental conditions when population numbers are higher than the current status.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The study area is not likely to support an important population.

Reduce the area of occupancy of an important population

The study area is not likely to support an important population.

Fragment an existing important population into two or more populations

The study area is not likely to support an important population.

Adversely affect habitat critical to the survival of a species

Using the koala habitat assessment tool (DotE 2013b), habitat in the study constitutes habitat critical to the survival of the Koala. The assessment on adverse effects was then undertaken and the results indicate that there is potential for the project to adversely affect habitat critical to the survival of the Koala (more details provided in **Section 5.7**). Up to 1.63% of foraging/breeding habitat and 1.46% of dispersal habitat in the study area would be directly or indirectly impacted, of which a portion would constitute habitat critical to the survival of the species.

Disrupt the breeding cycle of an important population

The study area is not likely to support an important population.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

The Koala has historically been recorded in the study area and is considered to use habitat in the study area for foraging and breeding during times of preferable environmental conditions. Over 98% of foraging, breeding and dispersal habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of the Koala. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of the Koala. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging and breeding habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of the Koala. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Koala in the study area, despite the potential for the project to adversely affect habitat critical to the survival of the Koala. Over 98% of the potential foraging, breeding and dispersal habitat in the study area would not be directly or indirectly impacted. The loss of less than 2% of potential habitat in the study area is unlikely to adversely affect the long-term survival of Koala due to the small percentage of potential habitat that would be impacted.

There are no recent sightings of Koala in the study area and the study area is unlikely to have historically supported a large population of Koala. The study area is unlikely to support an important population of Koala and does not provide key breeding habitat.

Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide important Koala habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

The project is not considered likely to interfere substantially with the recovery of the Koala, as the project is unlikely to result in increased koala fatalities due to dog attack or vehicle strike, is unlikely to result in the spread of disease or pathogens, is unlikely to create a barrier to movement to, between or within habitat critical to the survival of the Koala and is unlikely to change the hydrology of the study area.

With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

Despite this conclusion, residual impacts of the project on Koala will be offset in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

***Pseudomys pilligaensis* (Pilliga Mouse) – Vulnerable**

It is important to note that the Pilliga Mouse is now considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed & Ford 2007; Ford 2008), as cited in DoE 2014). Importantly, this taxonomic change has not yet been formally recognised under the EPBC Act (DotE 2016b); hence this assessment considers the Pilliga Mouse as currently listed.

The Pilliga Mouse is restricted to the Pilliga region of NSW, with the greatest density of records for the species occurring within the Pilliga Forest (OEH 2016b). The few records from outside the Pilliga include Binnaway Nature Reserve (approximately 30 km south-east of Coonabarabran) and Bebo State Forest (approximately 230 km north-east of Narrabri) (OEH 2016a; NPWS 2002b; Jarman & Green 2000). Its distribution is sparse and it is thought to undergo temporal fluctuations. The reasons for the irruptive population phases are unknown but may relate to recent fire history and high rainfall periods (Tokushima et al. 2008). This species has been recorded in the study area throughout the forested portion.

It is thought that primary habitat patches support this species playing an important role as refuge habitat during times of population contraction. A wider range of secondary habitat is used during a population irruption when environmental conditions are favourable (Tokushima et al. 2008). Primary habitat includes heathy woodland on sandy soils suitable for burrowing with a low and diverse shrubby layer and a diverse ground layer. Secondary habitat included shrubby and heathy woodland but with generally lower shrub diversity or cover. Consistent habitat features of most areas in which the Pilliga mouse has been recorded include high plant species richness, a moderate to high density of low shrubs, and a moist groundcover of plants, litter and fungi (Fox & Briscoe 1980; OEH 2016b; Tokushima et al. 2008). In the study area, the species is known to utilise heath, heathy woodland, riparian woodland, shrub-grass woodland and shrubby woodland habitats, and is predicted to also use grassy woodland habitats.

The population size of the Pilliga Mouse is hard to estimate, especially as demographics are irruptive. The population has been estimated to be approximately 50,000 to 100,000 during irruptive periods (Paull & Milledge 2011). Peak density has been calculated at 15-90 Pilliga Mice / ha in comparison to low density calculated at 0-5 Pilliga Mice / ha (Tokushima et al. 2008; DotE 2016b).

Within the study area, 8,595 ha of primary habitat and 14,609 ha of secondary habitat has been mapped. Both these habitat categories have potential to support breeding and foraging and in particular primary habitat supports Pilliga Mouse during population bust periods. There are 68,050 ha of habitat in the study area identified as dispersal habitat. The dispersal habitat comprises all primary and secondary habitat as well as additional habitat that could support Pilliga Mouse during boom periods. An upper limit of 889.31 ha of habitat would be directly impacted (135.04 ha of primary habitat, 181.51 ha of secondary habitat and 572.76 ha of dispersal habitat) which equates to 1.57% of primary habitat, 1.24% of secondary habitat and 0.84% of dispersal habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 162.87 ha of habitat (24.73 ha of primary habitat, 33.24 ha of secondary habitat and 104.9 ha of dispersal habitat) which would combine to impact a total of 1.86% primary habitat, 1.47% secondary habitat and 1.00% of dispersal habitat in the study area.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The project is unlikely to lead to a long-term decrease in the size of the Pilliga Mouse population. The study area supports breeding, foraging and dispersal and is considered part of a stronghold for the species. Over 98% of primary and secondary habitat and over 98% of dispersal habitat in the study area would not be directly or indirectly impacted. The non-impacted habitat is connected to additional primary, secondary and dispersal habitat in the study region. It is considered that this habitat would still support breeding, foraging and dispersal for this population in the study area.

The removal and reduction in habitat quality in less than 2% of the habitat is not likely to restrict breeding, foraging or dispersal for this species in the study area. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to cause a long-term decrease in the population.

Reduce the area of occupancy of an important population

The project is likely to reduce the area of occupancy of the Pilliga Mouse population. It is not possible to know the exact area of occupancy for this species in the study area as all known breeding and foraging sites have not been mapped. However, the direct impact on foraging and breeding habitat in the study area is likely to result in the removal of a portion of occupied habitat. Up to 135.04 ha of primary habitat and 181.51 ha of secondary habitat would be removed which constitutes less than 2% of the available primary and secondary habitat in the study area. It is possible that a portion of this habitat would be occupied by the species for forging and breeding.

Fragment an existing important population into two or more populations

The project is unlikely to fragment an existing population of Pilliga Mouse into two or more populations. This species is known to occur in the study area, with an existing population considered to use the study area for foraging and breeding.

The definition of fragmentation under the EPBC Act has not been defined. The effects of fragmentation are species specific, with the scale of the barrier effect being affected by road width, traffic volume and behaviour of the species (van der Ree et al. 2008). Narrow roads (3 m width) have been found to inhibit movement of small mammals, but not completely eliminate road crossing (Swihart & Slade 1984; Barnett et al. 1978).

During boom periods, the Pilliga Mouse is thought to be able to move across existing open spaces in the study area. Hence, during these times, the fragmentation associated with the project is not considered wide enough to inhibit dispersal. However, during bust periods when the Pilliga Mouse population is congregated within primary and secondary habitats, there is potential for the fragmentation of primary and secondary habitat patches to restrict movement. This may restrict current overlapping of home ranges, inhibiting breeding potential between individuals on either side of the corridor.

The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be the 30 m wide Bibblewindi to Leewood infrastructure corridor. The 30 m wide corridor would increase the intersection of three patches of primary habitat. These patches are currently separated by up to 10 m from the existing clearing. The smallest patch of primary habitat that would be separated by 30 m would be 5 ha. This patch of primary habitat would remain linked to a larger patch of primary habitat (57 ha) by 32 ha of secondary habitat. The remaining patches of primary habitat would be in patches of between 20 ha and 168 ha. All of the patches of primary habitat are connected to patches of secondary habitat with the mosaic of primary and secondary patches being completely connected on either side of the corridor. The habitat present on either side of the linear corridors is extensive and would support Pilliga Mouse foraging and breeding. With the ability to occasionally cross the corridor, it is not predicted that the individuals on either side of the corridor would be permanently fragmented from each other.

Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the Pilliga Mouse would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is likely to affect habitat critical to the survival of the Pilliga Mouse.

Habitat for Pilliga Mouse is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this species.

Using the definition for this assessment, all occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for foraging, breeding and dispersal and supports the genetic diversity and long-term evolutionary development of the species. Up to 1.86% of primary habitat, 1.47% of secondary habitat and 1.00% of dispersal habitat in the study area would be directly or indirectly impacted, of which a portion would be occupied and providing habitat critical to the survival of this species.

Disrupt the breeding cycle of an important population

The project is unlikely to disrupt the breeding cycle (mating, pregnancy, birth, lactating and rearing and dispersal) of the Pilliga Mouse population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals to occur within proximity such that genetic diversity is maintained through mating. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the birth of young and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.86% of primary habitat, 1.47% of secondary habitat and 1.00% of dispersal habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

The Pilliga Mouse has been recorded in the study area and is considered to use habitat in the study area for foraging and breeding. Over 98% of primary and secondary habitat and over 98% of dispersal habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement for this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of Pilliga Mouse. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of Pilliga Mouse. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging and breeding habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of Pilliga Mouse. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Pilliga Mouse.

The Pilliga Mouse has been recorded in the study area is considered to use habitat in the study area for foraging, breeding and dispersal. Over 98% of the foraging and breeding habitat and over 98% of the dispersal habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would fragment a population into two or more populations. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.8 Mammals: Endangered

Dasyurus maculatus (Spotted-tailed Quoll) – Endangered

The range of the Spotted-tailed Quoll has contracted considerably since European settlement. It now has a disjunct distribution along the east coast of Australia, extending from south-eastern Queensland through NSW and Victoria to Tasmania (OEH 2016b). The species was not observed during field surveys and there are no existing records for the species within the study area. Previous records of the Spotted-tailed Quoll in the Pilliga are sparse, with a record in the Pilliga Nature Reserve from 2006 and three records adjacent to the Pilliga forests (OEH 2016a). One record is from the Warrumbungles from 2008 and two records are south-east of the Pilliga forests from 1994 and 2004. While the species occurs more frequently in coastal areas, there are scattered records for Spotted-tailed Quolls west of the study area along the Barwon River.

The Spotted-tailed Quoll inhabits a range of environments including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline (DotE 2016b). The Spotted-tailed Quoll uses a range of habitat within its large home range (up to 750 ha for females and up to 3,500 ha for males; OEH 2014b). Important habitat features include densely-vegetated creek lines for movement; hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky cliff-faces for den sites; and flat rocks among boulder fields and rocky cliff-faces for latrine sites. The species requires habitat that supports a wide range of prey including gliders, possums, small wallabies, rats, birds, bandicoots, rabbits and insects (OEH 2016b). Within the study area, all habitat types are considered predicted habitat for the species.

Within the study area, approximately 80,498 ha of habitat has been mapped which provides 80,498 ha of foraging habitat and 69,532 ha of breeding habitat. Within the study region, approximately 357,191 ha of habitat has been mapped which provides 357,191 ha of foraging habitat and 302,437 ha of breeding habitat. An upper limit of 988.80 ha of habitat would be directly impacted (988.80 ha of foraging habitat and 885.00 ha of breeding habitat) which equates to 1.23% of foraging and 1.27% of breeding habitat directly impacted in the study area. Indirect impacts have the potential to modify additional habitat. The reduction in habitat quality would be comparable to additional loss of up to 181.11 ha of habitat (181.11 ha of foraging habitat and 175.41 ha of breeding habitat) which would combine to impact a total of 1.45% of foraging habitat and 1.53% of breeding habitat in the study area.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population

The project is unlikely to lead to a long-term decrease in the size of the Spotted-tailed Quoll population. The study area supports both potential breeding and foraging but the species has not been recorded in the study area. Over 98% of foraging habitat and 98% of breeding habitat in the study area would not be directly or indirectly impacted. The non-impacted habitat is connected to additional foraging and breeding habitat in the study region in which the species has been recorded. It is considered that the habitat would still support breeding and foraging for this population in the study area.

The removal and reduction in habitat quality in less than 2% of the habitat is not likely to restrict breeding or foraging for this species in the study area. Due to the minimisation of impacts to key habitat features, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat is not likely to cause a long-term decrease in the population.

Reduce the area of occupancy of the species

The project is unlikely to reduce the area of occupancy of the Spotted-tailed Quoll. This species is not known to occupy the study area and hence no habitat in the study area is considered an area of occupancy for this species.

Fragment an existing population into two or more populations

The project is unlikely to fragment an existing population of Spotted-tailed Quoll into two or more populations. This species is not known to occur in the study area, with an existing population considered to potentially use the study area for foraging or breeding.

Up to 988.80 ha of foraging habitat and 885.00 ha of potential breeding habitat which constitutes approximately 1.23% of foraging and 1.27% of breeding habitat in the study area would be removed and would increase the fragmentation in the study area. It is likely that additional patches of habitat would be formed. Due to the scale of the proposed infrastructure, the additional patches are not considered 'isolated' as the species would have the mobility to move between patches. The majority of linear fragmentation would be an average width of 10 m and rehabilitated directly after impact to 5 m. The widest linear corridor proposed would be up to 30 m wide. These linear clearing widths would not prevent movement by the species. Major infrastructure at Bibblewindi and drillers camps would be placed to minimise isolating habitat patches and would be surrounded by habitat such that movement by the three assessed species would be possible around the infrastructure.

Adversely affect habitat critical to the survival of a species

The project is unlikely to adversely affect habitat critical to the survival of the Spotted-tailed Quoll. Habitat for Spotted-tailed Quoll is not listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. There is no recovery plan for this species.

Using the definition for this assessment, occupied habitat for this species in the study area is considered critical to the survival of the species as it is necessary for foraging, breeding, roosting and dispersal and supports the genetic diversity and long-term evolutionary development of the species. No known occupied habitat occurs in the study area and habitat that could be used on occasion for foraging or breeding is not considered to be critical to the survival of this species.

Disrupt the breeding cycle of a population

The project is unlikely to disrupt the breeding cycle (mating, pregnancy, birth, lactating and rearing and dispersal) of the Spotted-tailed Quoll population.

The breeding cycle can be impacted by direct impacts of habitat removal or by indirect impacts (discussed in **Section 6.4**) which are undertaken during important stages of the species' lifecycle or which reduce habitat quality.

Successful completion of the breeding cycle requires adequate numbers of individuals to occur within proximity such that genetic diversity is maintained through mating. For the breeding cycle to be disrupted, stages of the cycle would have to be inhibited over consecutive seasons for a significant proportion of the population. In this case, the birth of young and the regeneration of the population would be significantly prevented.

Impacts to the breeding cycle would be mitigated by staged construction, progressive rehabilitation, controlling feral fauna and weeds and not directly or indirectly impacting more than 1.53% of breeding habitat in the study area. The breeding cycle would be still able to be successfully completed in the study area during all stages of the project.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Spotted-tailed Quoll has not been recorded in the study area and is considered to potentially use habitat in the study area for foraging and breeding. Over 98% of foraging habitat and 98% of breeding habitat in the study area would be maintained with no impact to the quality and availability of the maintained habitat. The scale of the fragmentation would not significantly inhibit the movement of this species and hence patches of occupied and unoccupied habitat would not be isolated.

Due to the minimisation of indirect impacts by restricting access outside of the disturbance footprints, progressive rehabilitation and staged construction, the magnitude and duration of the direct and indirect impacts on habitat for this species is not likely to cause the species to decline.

Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

The project is unlikely to result in establishment of invasive species in potential foraging habitat of the Spotted-tailed Quoll. Historical land use in the study area has led to the establishment of a suite of invasive species that are potentially harmful to this species' habitat (**Appendix C**). However, it is unlikely that additional invasive species would become established in the study area including in habitat for this species.

The feral animal control strategy and pest and weed management plan proposed to be implemented as part of the project would manage and monitor feral animal, pest and weed species in the study area and study region with the aim of reducing pressures from invasive species in the study area.

Introduce disease that may cause the species to decline, or

The project is unlikely to result in the introduction of disease that may cause decline of the Spotted-tailed Quoll. There is potential for disease caused by the soil-borne plant pathogen *Phytophthora cinnamomi* to occur in the study area as a result of the project. This pathogen could impact on the vegetation communities that could support foraging and breeding habitat for this species. The study area is not within a known vulnerable climatic zone but the potential extent of the pathogen in Australia is not completely known (DotE 2014b). Control of transportation of the pathogen would occur by controlling soil transportation into the study area. Vehicle wash down points and inspections would be applied throughout the construction and operation phases.

Interfere substantially with the recovery of the species.

The project is unlikely to interfere substantially with the recovery of the Spotted-tailed Quoll. The biodiversity monitoring proposed to be undertaken as part of the project would monitor the status of this species and its habitat in the study area including distribution, abundance and possible or observed threats. The monitoring would ensure that proposed mitigation measures are substantially managing this species and its habitat and would trigger additional action if required.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact Spotted-tailed Quoll in the study area.

Spotted-tailed Quoll has not been recorded in the study area and is not considered to use habitat in the study area as a reliable foraging or breeding resource. Over 98% of potential foraging habitat and 98% of potential breeding habitat in the study area would not be directly or indirectly impacted. The removal of habitat for this species in the study area is not considered at a scale that would isolate patches such that movement could not occur between patches. Hence, the fragmentation impacts are not considered to be at a scale that would impact this species. Additionally, it is unlikely that invasive species or disease that could impact the species would be established in the study area as a result of the project. With the implementation of the Field Development Protocol and proposed avoidance, minimisation and mitigation measures, the magnitude and duration of the direct and indirect impacts on this species are not considered likely to impact its long-term survival in the study area.

1.9 Migratory species (not already addressed in above assessments)

Apus pacificus (Fork-tailed Swift), *Ardea ibis* (Cattle Egret), *Ardea modesta* (Great Egret), *Calidris acuminata* (Sharp-tailed Sandpiper), *Gallinago hardwickii* (Latham's Snipe), *Hirundapus caudacutus* (White-throated Needletail), *Merops ornatus* (Rainbow Bee-eater), *Myiagra cyanoleuca* (Satin flycatcher) and *Plegadis falcinellus* (Glossy Ibis) are considered in this assessment.

Apus pacificus (Fork-tailed Swift) – Migratory and Marine

The Fork-tailed Swift is listed migratory under the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) (DotE 2016b). It is a non-breeding visitor to all states and territories of

Australia (Higgins 1999), arriving from its breeding grounds in Siberia around October, and departing in April. The species is thought to be highly mobile within Australia, moving across the country in search of food. In NSW, the Fork-tailed Swift is recorded in all regions. Many records occur east of the Great Divide, although a few scattered populations have been found west of the line joining Bourke and Dareton. Sightings have been recorded at Milparinka, the Bulloo River and Thurloo Downs (DotE 2016b).The species has been recorded to the east of the study area, on the Liverpool Plains (OEH 2014b) and was observed flying over the study area.

The species has been recorded using a wide variety of habitats, with a tendency to occur over inland plains but also over coasts and urban areas (Simpson & Day 2010). They mostly occur over dry or open habitats, including riparian woodland and tea-tree swamps, low scrub, heathland or saltmarsh, as well as treeless grassland, Spinifex sandplains, open farmland and inland and coastal sand-dunes. Less commonly, they are seen above rainforests, wet sclerophyll forest or open forest or plantations of pines (Higgins 1999). The Fork-tailed Swift is predicted to utilise all habitat types within the study area.

The Fork-tailed Swift is an aerial forager, often feeding along the edge of low-pressure systems to hundreds of metres above the ground. They may also forage aerially at less than one metre above open areas or over water, or sometimes among tree-tops in open forest (Higgins 1999). They probably roost aerially, but are occasionally observed to land (Higgins 1999).

There are 80,498 ha of foraging habitat and 0 ha of breeding habitat mapped in the study area. There are 357,191 ha of foraging habitat and 0 ha of breeding habitat mapped in the study region. An upper limit of 988.80 ha of foraging habitat would be directly impacted which equates to 1.23% directly impacted in the study area. Up to an additional 181.11 ha of foraging habitat would be indirectly impacted which would combine to impact a total of 1.45% in the study area.

Ardea ibis (Cattle Egret) – Migratory and Marine

The Cattle Egret is listed under the Japan-Australia Migratory Bird Agreement (JAMBA) as *Bubulcus ibis*, and the China-Australia Migratory Bird Agreement (CAMBA) as *Ardeola ibis* (DotE 2016b). It is a widespread and common species in Australia. This species has been recorded in the northern portion of the study area (DotE 2014a).

The Cattle Egret occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands, and very rarely in arid and semi-arid regions. It uses predominately shallow, open and fresh wetlands including meadows and swamps with low emergent vegetation and abundant aquatic flora. The Cattle Egret often forages away from water on low lying grasslands, improved pastures and croplands. It is commonly found amongst livestock (Marchant & Higgins 1990). Predicted habitat for the species within the study area includes water bodies and grasslands.

There are 9,565 ha of foraging habitat and 0 ha of breeding habitat mapped in the study area. There are 40,739 ha of foraging habitat and 0 ha of breeding habitat mapped in the study region. An upper limit of 75.90 ha of foraging habitat would be directly impacted which equates to 0.79% directly impacted in the study area. No foraging habitat would be indirectly impacted.

Ardea modesta (Great Egret) – Migratory and Marine

The Great Egret is included in the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA). Under both these agreements, it is listed as *Egretta alba.* The Great Egret is common and widespread in Australia, occurring in all states and territories. They have also been recorded as vagrants on Lord Howe, Norfolk and Macquarie Islands (DotE 2016b) The Great Egret has been observed in the study area.

The Great Egret has been reported in a wide range of wetland habitats including swamps and marshes; margins of rivers and lakes; damp or flooded grasslands, pastures or agricultural lands; reservoirs; sewage treatment ponds; drainage channels; salt pans and salt lakes; salt marshes; estuarine mudflats, tidal streams; and mangrove swamps (Kushlan & Hancock 2005; Marchant & Higgins 1990). The Great Egret may retreat to permanent wetlands or coastal areas when other wetlands are dry (for example, during drought). Predicted habitat within the study area includes waterbodies and grasslands.

In Australia, the largest and most concentrated breeding colonies are located in near-coastal regions of the Top End of the Northern Territory. Other major breeding colonies are found in the Channel Country of south-western Queensland, north-eastern South Australia the Darling Riverine Plains region of NSW and the Riverina region of NSW and Victoria. Minor breeding sites are widely scattered across the species' range.

There are 9,565 ha of foraging habitat and 0 ha of breeding habitat mapped in the study area. There are 40,739 ha of foraging habitat and 0 ha of breeding habitat mapped in the study region. An upper limit of 75.90 ha of foraging habitat would be directly impacted which equates to 0.79% directly impacted in the study area. No foraging habitat would be indirectly impacted.

***Calidris acuminata* (Sharp-tailed Sandpiper) – Migratory and Marine**

The Sharp-tailed Sandpiper is included in the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) (DotE 2016b). It breeds in northern Siberia, and most of the population migrates to spend the non-breeding season in Australia, arriving in August and departing by April. Most move across the continent to south-eastern Australia, where they occur in both inland and coastal locations and in both freshwater and saline habitats. Many inland records are of birds on passage (DotE 2016b). They are widespread in most regions of NSW, especially in coastal areas, but they are sparse in the south-central western plain and east lower western regions of NSW. The species was observed in wetland habitat in Narrabri.

In Australasia, the Sharp-tailed Sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline saltlakes inland. They also use flooded paddocks, sedgelands and other ephemeral wetlands, but leave when they dry (Higgins & Davies 1996). The species forages at the edge of the water in wetlands or intertidal mudflats, among inundated vegetation such as grass or sedges, sewage ponds, and often in hypersaline environments. After rain, they may forage in paddocks of short grass, well away from water. Waterbodies are the predicted habitat for the species within the study area.

No foraging habitat in the study area will be directly or indirectly impacted. There is no breeding habitat mapped in the study area.

***Gallinago hardwickii* (Latham's Snipe) – Migratory and Marine**

Latham's Snipe is included in the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) (DotE 2016b). It is a non-breeding migrant to Australia, arriving between July-November from its breeding grounds in Japan and far-eastern Russia, and departing by late February. It has been recorded along the east coast of Australia from Cape York Peninsula through to south-eastern South Australia with most birds spending the non-breeding season in south-eastern Australia. The range extends inland west of the Great Dividing Range in New South Wales (DotE 2016b). Whilst the species has not been recorded within the study area, there are nearby records from the southern Pilliga, Narrabri, and to the north-west of Narrabri (OEH 2016a).

This species occurs in permanent and ephemeral wetlands up to 2000 m above sea-level, usually inhabiting open, freshwater wetlands with low, dense vegetation such as swamps, flooded grasslands or heathlands, around bogs and other water bodies (DotE 2016b). This species can also occur in habitats with saline or brackish water and in modified or artificial habitats. It feeds in mud, either exposed or in very shallow water with low, dense vegetation. Roosting occurs on the ground near or in foraging areas beside or under clumps of vegetation, among dense tea-tree, in forests, in drainage ditches or plough marks, among boulders, or in shallow water if cover is unavailable. Water bodies are the predicted habitat in which the species could occur in the study area.

No foraging or breeding habitat in the study area will be directly or indirectly impacted.

***Hirundapus caudacutus* (White-throated Needletail) – Migratory and Marine**

The White-throated Needletail is included in the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), and as *Chaetura caudacuta* under the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) (DotE 2016b). It breeds in eastern Siberia, north-eastern China and Japan (DotE 2016b). The species arrives in Australia in September–October, and most depart by April. During this non-breeding season, it is widespread in eastern and south-eastern Australia, recorded in all coastal regions of Queensland and NSW, extending inland to the western slopes of the Great Divide and occasionally onto the adjacent inland plains. The White-throated Needletail has been recorded in the study area.

In Australia, the White-throated Needletail is almost exclusively aerial, from heights of less than 1 metre up to more than 1000 metres above the ground. Despite being aerial, the species exhibits certain habitat preferences. Although they occur over most types of habitat, they are probably recorded most often open forest and rainforest, and are less commonly recorded flying above woodland. They also commonly occur over heathland, but less often over treeless areas like grassland or swamps. When flying above farmland, they are more often recorded above partly cleared pasture, plantations or remnant vegetation at the edge of paddocks (DotE 2016b). Within the study area, this species is known to occur in heath and riparian woodland habitats, and is predicted to occur in all other habitat types.

The White-throated Needletail almost always forage aerially. The species has been recorded roosting in trees in forests and woodlands, both among dense foliage in the canopy or in hollows. It has been suggested that they also sometimes roost aerially (DotE 2016b).

There are 80,498 ha of foraging habitat and 69,532 ha of roosting habitat mapped in the study area. There are 357,191 ha of foraging habitat and 302,437 ha of roosting habitat mapped in the study region. An upper limit of 988.80 ha of foraging habitat and 885.00 ha of roosting habitat would be directly impacted which equates to 1.23% and 1.27% directly impacted in the study area of foraging and roosting habitat respectively. Up to an additional 181.11 ha of foraging habitat and 175.41 ha of roosting habitat would be indirectly impacted which would combine to impact a total of 1.45% and 1.53% in the study area.

***Merops ornatus* (Rainbow Bee-eater) – Migratory and Marine**

The Rainbow Bee-eater is included in the Japan-Australia Migratory Bird Agreement (JAMBA). It is distributed across much of mainland Australia and several near-shore islands, although it is only sparsely distributed in the most arid regions of central and Western Australia. It has been recorded in the study area.

The species mainly occurs in open forests and woodlands, shrublands, and various cleared or semi-cleared habitats, including farmland and areas of human habitation. It usually occurs in open, cleared or lightly-timbered areas that are often, but not always, located in proximity to permanent water. It also occurs in inland and coastal sand dune systems, and in mangroves in northern Australia, and has been recorded in various other habitat types including heathland, sedgeland, vine forest and vine thicket, and on beaches (DotE 2016b). In the study area, it is known to utilise a range of habitat types, including water bodies, grassy woodlands, heathy woodland, riparian woodland and shrub-grass woodland. It is predicted to also use grassland and heath habitats.

In Australia, the breeding season extends from August to January (Higgins 1999). The nest is constructed in an enlarged chamber at the end of long burrow that is excavated, by both sexes, in flat or sloping ground, in riverbanks, creeks or dams, in roadside cuttings, in the walls of gravel pits or quarries, in mounds of gravel, or in cliff-faces. Populations that breed in southern Australia are migratory, with birds moving north to northern Australia, Papua New Guinea and eastern Indonesia after breeding, and remaining there for the duration of the Australian winter (Higgins 1999). Conversely, populations that breed in northern Australia are considered to be resident, and in many northern localities the Rainbow Bee-eater is present throughout the year (DotE 2016b).

There are 77,671 ha of foraging habitat and 66,805 ha of breeding habitat mapped in the study area. There are 340,751 ha of foraging habitat and 292,431 ha of breeding habitat mapped in the study region. An upper limit of 965.60 ha of foraging habitat and 861.80 ha of breeding habitat would be directly impacted in the study area which equates to 1.24% and 1.29% of foraging and breeding habitat respectively. Up to an additional 176.41 ha of foraging habitat and 170.71 ha of breeding habitat would be indirectly impacted which would combine to impact a total of 1.47% and 1.55% in the study area.

Myiagra cyanoleuca (Satin flycatcher) – Migratory and Marine

The Satin Flycatcher is listed as migratory under the family Muscicapidae in the Convention on Migratory Species (DotE 2016b). It is widespread in eastern Australia and vagrant to New Zealand (Blakers et al. 1984). In NSW, they are widespread on and east of the Great Divide and sparsely scattered on the western slopes, with very occasional records on the western plains (DotE 2016b) The species is known to occur in the study area.

Satin Flycatchers mainly inhabit eucalypt-dominated forests, often near wetlands or watercourses, and frequently utillise heavily-vegetated gullies (Blakers et al. 1984; Emison et al. 1987; Officer 1969). They also occur in drier eucalypt woodlands with open understorey and grass ground cover. Within the study area the Satin Flycatcher is known to utilise riparian woodland and shrub-grass woodlands and are predicted to use waterbodies, heathy woodlands and grassy woodlands.

Satin Flycatchers move north in autumn to spend winter in northern Australia and New Guinea and returning south in spring (Blakers et al. 1984). In NSW, they depart between February and March and return between September and October. In NSW, breeding occurs between November and March, with a nest usually built in the high, exposed outer branches of a tree, generally a eucalypt (DotE 2016b).

There are 66,805 ha of foraging habitat and 66,705. ha of breeding habitat mapped in the study area. There are 292,431 ha of foraging habitat and 287,870 ha of breeding habitat mapped in the study region. An upper limit of 861.80 ha of foraging and breeding habitat would be directly impacted which equates to 1.29% directly impacted in the study area. Up to an additional 170.71 ha of foraging and breeding habitat would be indirectly impacted which would combine to impact a total of 1.55% in the study area.

Plegadis falcinellus (Glossy Ibis) – Migratory and Marine

The Glossy Ibis is included in the China-Australia Migratory Bird Agreement (CAMBA) and listed as a migratory species in the Convention on Migratory Species (DotE 2016b). It is recorded over much of NSW, migrating to the southern Murray-Darling region and Macquarie Marshes to breed over spring and summer. It has previously been recorded at Yarrie Lake in the north of the study area.

The Glossy Ibis is known to use a range of aquatic habitats including edges of lakes and rivers, lagoons, flood-plains, wet meadows, swamps, reservoirs, sewage ponds, rice fields and cultivated areas under irrigation. They also occasionally use estuaries, deltas, saltmarshes and coastal lagoons.

No foraging or breeding habitat in the study area would be directly or indirectly impacted.

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species

The project is unlikely to substantially modify, destroy or isolate an area of important habitat for the assessed migratory species.

Using the definition for this assessment, important habitat for the assessed migratory species does not occur in the study area as the study area is not considered to support an ecologically significant proportion of the population of these species. Additionally, the habitat in the study area is not of critical importance to the species during the life cycle. None of the assessed migratory species are at the limit of their range in the study area, nor are they known to be declining in the study area. It is important to note that Satin Flycatcher predominantly occurs east of the great divide with only scattered records further west than the study area.

For those species that require aquatic habitat (Sharp-tailed Sandpiper, Latham’s Snipe and Glossy Ibis), no foraging or breeding habitat would be directly or indirectly impacted.

Of the assessed migratory species, the Rainbow Bee-eater and Satin Flycatcher are the only species that potentially would breed the study area and could have its breeding habitat directly and indirectly impacted. Over 98% of the breeding habitat in the study area for these species would not be impacted on.

Foraging habitat in the study area would be directly or indirectly impacted for Fork-tailed Swift (1.45%), Cattle Egret (0.79%), Great Egret (0.79%), White-throated Needletail (1.45%), Rainbow Bee-eater (1.47%) and Satin Flycatcher (1.55%).

The direct and indirect impacts to the assessed migratory species are not considered to cause a decline of the species in the study area and hence would not lead to the study area aligning to the ‘important habitat’ definition.

Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or

The project is unlikely to result in an invasive species that is harmful to the assessed migratory species becoming established in an area of important habitat.

Using the definition for this assessment, important habitat for the assessed migratory species does not occur in the study area as the study area is not considered to support an ecologically significant proportion of the population of these species. Additionally, the habitat in the study area is not of critical importance to the species during the life cycle. None of the assessed migratory species are at the limit of their range in the study area, nor are they known to be declining in the study area.

Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Using the definition for this assessment, there is not considered to be an ecologically significant proportion of the assessed migratory species' populations that would rely on the study area for stages of the lifecycle such that their lifecycles are seriously disrupted by the project.

None of the assessed migratory species populations are listed as threatened in NSW or Australia. The species that are known to occur in the study area are not considered to be genetically distinct to individuals that occur in habitat in the study region or more broadly in the central-west region.

Conclusion

The results from this assessment indicate that the project is unlikely to significantly impact the assessed migratory species in the study area.

The study area is not considered to support important habitat for the assessed migratory species and hence the project would not substantially modify, destroy or isolate areas of important habitat. Additionally, no invasive species would be established in important habitat as a result of direct or indirect impacts.

In addition, the study area is not known to support an ecologically significant proportion of the population of these species.

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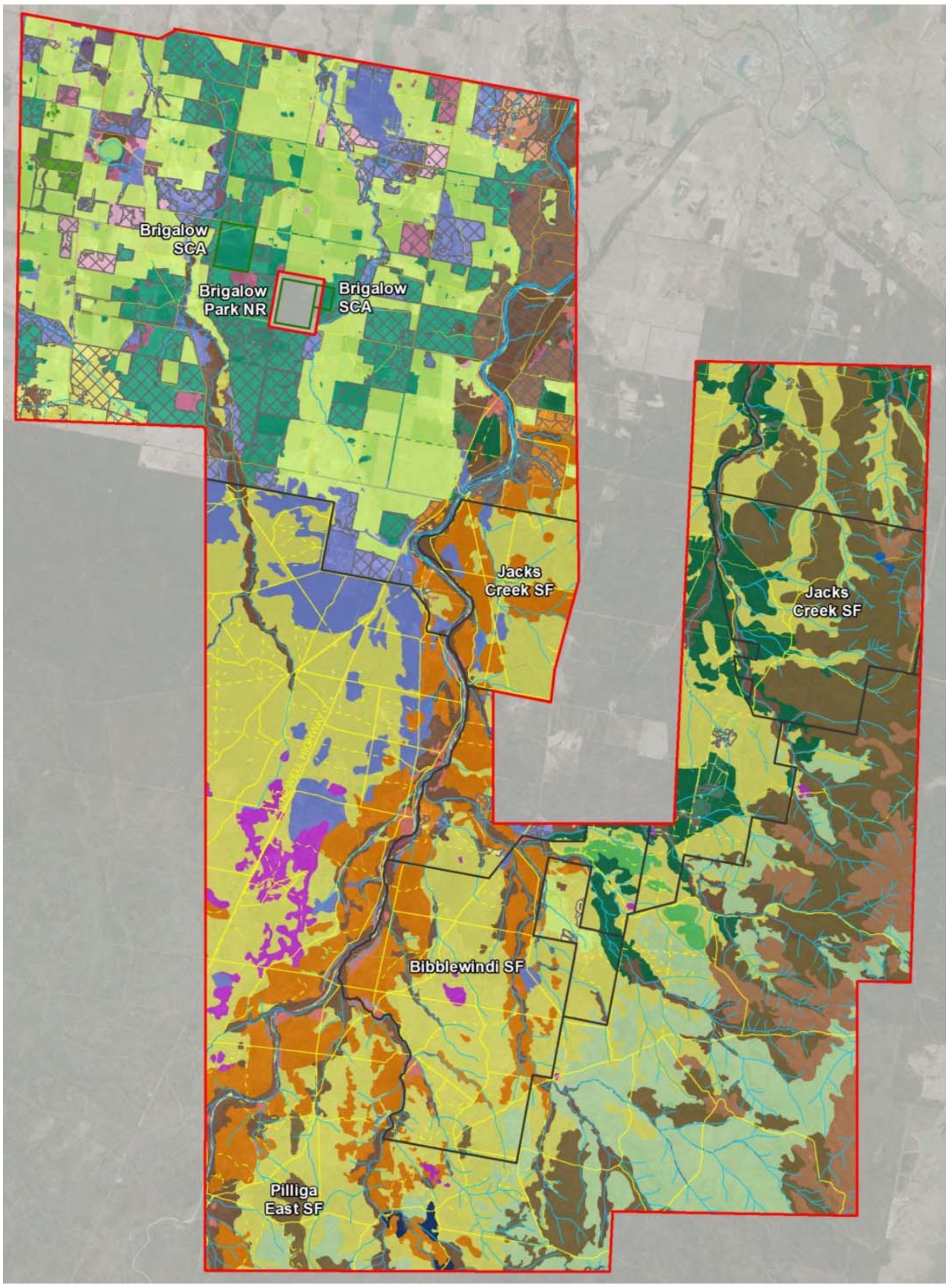
Appendix L: Biodiversity Offset strategy

Narrabri Gas Project

Working Draft: Biodiversity Offset Strategy

Prepared for
Santos NSW (Eastern) Pty Ltd

October 2015



This report should be cited as 'Eco Logical Australia 2014. *Narrabri Gas Project Biodiversity Offset Strategy*. Prepared for Santos Limited.'

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Contents

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Abbreviations

Abbreviation	Description
BBAM	Biobanking Assessment Methodology
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
DoTE	Commonwealth Department of Environment
DPE	NSW Department of Planning and Environment
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EPA Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
IBRA	Interim Biogeographic Regionalisation for Australia
LALC	Local Aboriginal Land Council
MNES	Matters of National Environmental Significance
NPW Act	NSW *National Parks and Wildlife Act 1974*
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
TSC Act	NSW *Threatened Species Conservation Act 1995*

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) being prepared to support 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. 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:

- *An assessment of the likely biodiversity impacts of the development, having regard to the principles and strategies in the draft NSW Biodiversity Offsets Policy for Major Projects, and the OEH's and NSW Trade and Investments' requirements, and using a suitable methodology for credit calculation (for instance,* [Biobanking assessment methodology] *BBAM or* [Framework for Biodiversity Assessment] *FBA).*
- *A comprehensive offset strategy for the project, using a suitable methodology for calculating the credits of any offsets*

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 Offset 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.

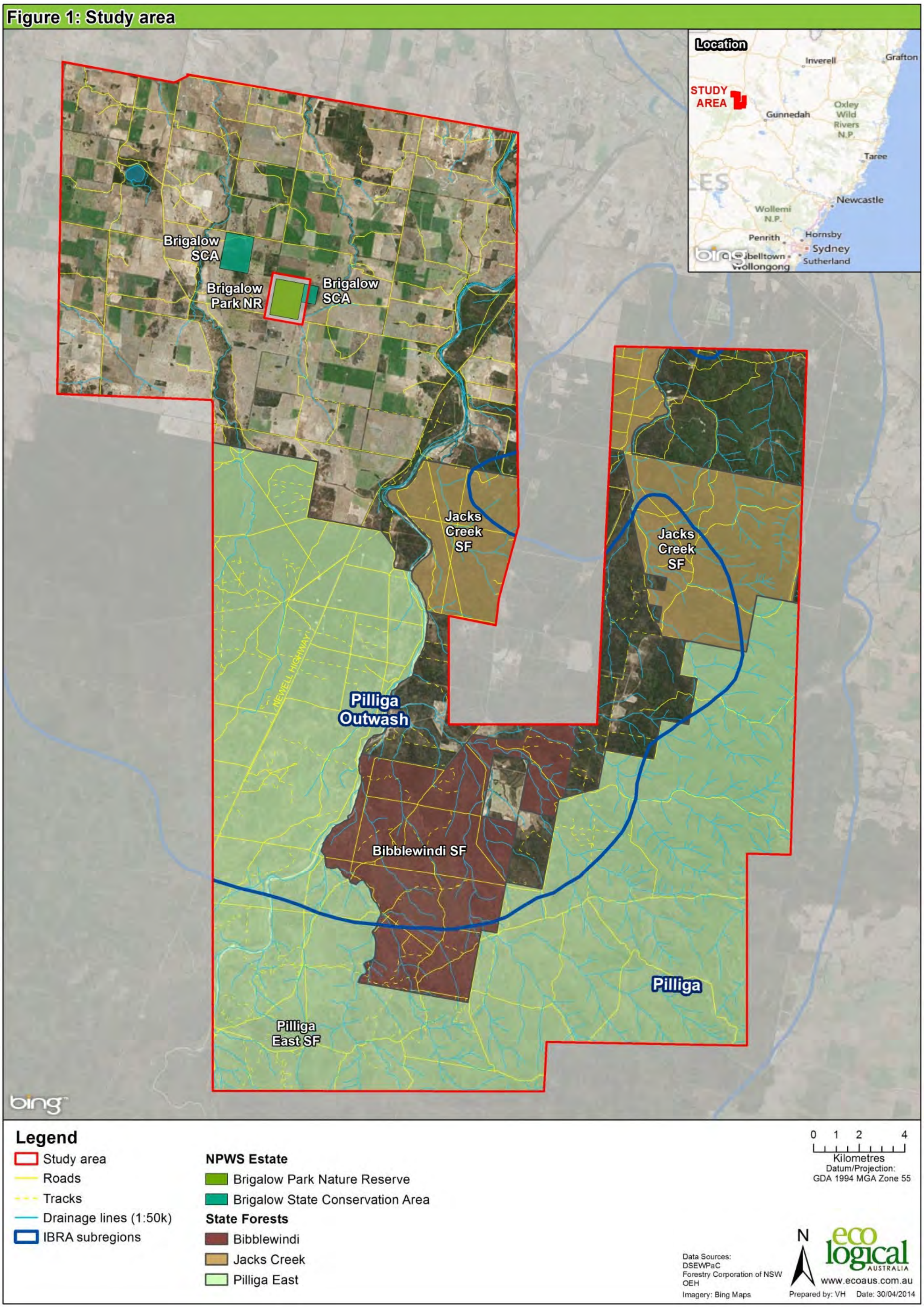

Figure 1: Study area

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 *Threatened Species Conservation Act 1995* (TSC 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 Matters of National Environmental Significance, offsets determined under the *NSW Biodiversity Offset Policy for Major Projects* are considered likely 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 Offset 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 OEH Northern Plains Region office 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 Offset Fund (once established).

2.3 Offset requirements to achieve long-term conservation outcomes

The project will result in the removal of up to 988.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.

A Major Project assessment was undertaken by an accredited Biobank Assessor using the Framework for Biodiversity Assessment (Major Projects Credit Calculator Version 4.1) inform the 'quantum' of biodiversity offsets required for the project. Four key elements were considered:

- **Direct impacts** – 988.8 ha (split between direct impacts and areas subject to immediate rehabilitation) - 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 utilised by the project
- **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 327 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 Biometric Vegetation Types (BVTs) were compiled for the assessment.

Biometric data from 327 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.

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 four 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 13.8 for this attribute.
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 manually selected.
    - 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 has 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 considered potentially or known 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.

Step 3 - Enter vegetation zones

Based on the data compiled in Step 1, a total of 32 vegetation zones were entered into the Major Projects Credit Calculator. 100 hectares were entered against each Plant Community Type Impacted and 100 hectares were entered against each Plant Community Type to be rehabilitated. 100 hectares was entered so that detailed analysis of the contribution of direct impacts, indirect impacts, cumulative impacts and rehabilitation on offset requirements could be determined outside of the Major Projects Credit Calculator. 100 hectares was used as it is a large enough number to reduce the subsequent impacts of rounding (compared to if 1 hectare was used).

Due the requirement for up to four management zones per Plant Community type (i.e. native vegetation, native vegetation rehabilitation, derived native vegetation, and derived native vegetation rehabilitation) and for ease of analysis, the assessment was split across two identical versions of the assessment in the Major Projects Credit Calculator.

Due to the complex nature of the project, it is not possible to completely assess the offset liability within the Major Projects Credit Calculator, however the intent of the Framework of Biodiversity Assessment has been maintained with this approach.

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 on ridges of gilgai clays – YES.

- Land north of Gunnedah in Liverpool Plains (Part B) CMA subregion – NO
- Seasonally wet/boggy sites (including table drains) – 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 20 species were identified as requiring survey by the Major Projects Credit Calculator 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	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bluegrass	*Dichanthium setosum*	Yes	Yes	Yes	Yes	Yes							Yes
Coolabah Bertya	*Bertya opponens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cyperus conicus	*Cyperus conicus*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Eastern Pygmy-possum	*Cercartetus nanus*	Yes	Yes	Yes	Yes					Yes	Yes	Yes	Yes
Five-clawed Worm-skink	*Anomalopus mackayi*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Greenhood Orchid	*Pterostylis cobarensis*									Yes	Yes	Yes	
Grey Falcon	*Falco hypoleucos*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Koala	*Phascolarctos cinereus*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Narrow Goodenia	*Goodenia macbarronii*#	Yes	Yes							Yes	Yes	Yes	Yes
Native Milkwort	*Polygala linariifolia*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pale-headed Snake	*Hoplocephalus bitorquatus*	Yes	Yes	Yes	Yes						Yes	Yes	Yes
Pine Donkey Orchid	*Diuris tricolor*									Yes	Yes		
Prasophyllum sp. Wybong	*Prasophyllum sp. Wybong*										Yes		

Common name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rufous Bettong	*Aepyprymnus rufescens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rulingia procumbens	*Rulingia procumbens*	Yes	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes
Scant Pomaderris	*Pomaderris queenslandica*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Slender Darling Pea	*Swainsona murrayana*	Yes	Yes							Yes	Yes	Yes	Yes
Spiny Peppercress	*Lepidium aschersonii*	Yes	Yes	Yes	Yes	Yes				Yes	Yes	Yes	Yes
Squirrel Glider	*Petaurus norfolcensis*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tylophora linearis	*Tylophora linearis*	Yes	Yes	Yes	Yes	Yes				Yes	Yes	Yes	Yes

Goodenia macbarronii 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. This step also requires the assessor to assign management zones to each vegetation zone. Two management zones were defined: development (complete clearing); and partial rehabilitation (partial clearing). For development areas, the default '0' was applied to site value scores (indicating complete clearing). For partial rehabilitation, site value scores were manually adjusted from the current maximum value to the following values:

- Native species richness = '1'
- Native overstorey cover = '1'
- Native midstorey cover = '1'
- Native ground cover (grasses) = '1'
- Native ground cover (shrubs) = '1'
- Native ground cover (other) = '1'
- Exotic plant cover = same as original plot data
- Number of trees with hollows = '0'
- Proportion of over-storey species occurring as regeneration = '1'
- Total length of fallen logs = same as original plot data

The rationale for the modification to site value scores for partial rehabilitation management scores is as follows:

- Native species richness is unlikely to change as a result of the project due to the effective management of topsoil and the soil seedbank (and actually is likely to increase), however a precautionary approach has been taken and a reduction in site value from a maximum of '3' to '1' has been taken.
- Native plant cover will be reduced initially following clearing, but will regenerate rapidly over time. As such, a reduction in native plant cover from a maximum of '3' to '1' has been taken.

- Exotic plant cover is unlikely to increase as a result of the project due to the commitment to prepare and implement a pest plant and animal management plan.
- The number of trees with hollows will be reduced to ‘0’ in development areas as a result of the project. The installation of nest boxes is not currently a supported method for the replacement of hollows in the Framework for Biodiversity Assessment.
- The proportion of over-storey species occurring as regeneration is unlikely to change as a result of the project due to the effective management of topsoil and the soil seedbank.
- Total length of fallen logs is unlikely to change as a result of the project and is more likely to increase due to the respreading of felled timber.

The proposed rehabilitation methodology for the project differs significantly from traditional mine site rehabilitation in that the subsoil structure, water infiltration and nutrient cycling are largely unaffected during construction.

A comprehensive rehabilitation strategy has been prepared as part of the EIS (Appendix V of the EIS). 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.

The rehabilitation strategy for the project utilises the inherent capacity of the native vegetation of the Pilliga to regenerate. Progressive rehabilitation has been undertaken in the study area for a selection of well pads and linear infrastructure as part of existing exploration and appraisal activities. Monitoring of this rehabilitation has been undertaken since 2012 and has shown that on average, rehabilitation sites approximate 74% of the site value of reference sites within relatively short timeframes (<5 years).

The methodology specified above for determining the site value of partial rehabilitation management zones results in approximately 68% of the credits required for development areas (complete clearing). This is consistent with the demonstrated ability of rehabilitation sites to approximate reference sites within relatively short periods as outlined above.

Step 7 - Threatened species survey results

This step requires the assessor to enter all ‘species credit’ species likely to be impacted by the development. This includes 9 threatened flora and 4 threatened fauna species. Only those species detected during detailed field surveys in the study area were included (**Table 2**).

Table 2: 'Species credit' species assessed

Name	Scientific name *
Black-striped Wallaby	*Macropus dorsalis*
Coolabah Bertya	*Bertya opponens*
Eastern Pygmy-possum	*Cercartetus nanus*
Greenhood Orchid	*Pterostylis cobarensis*
Native Milkwort	*Polygala linariifolia*
Pale-headed Snake	*Hoplocephalus bitorquatus*
Pine Donkey Orchid	*Diuris tricolor*

Name	Scientific name *
Rulingia procumbens	*Rulingia procumbens*
Scant Pomaderris	*Pomaderris queenslandica*
Spiny Peppercress	*Lepidium aschersonii*
Winged Peppercress	*Lepidium monoplocoides*
Squirrel Glider	*Petaurus norfolcensis*
Tylophora linearis	*Tylophora linearis*

For flora, 100 individuals were entered, while for fauna 100 hectares were entered. Similarly to vegetation zones, '100' was entered as the base unit so that detailed analysis of the contribution of direct impacts, indirect impacts, cumulative impacts and rehabilitation on offset requirements could be determined outside of the Major Projects Credit Calculator. 100 hectares was used as it is a large enough number to reduce the subsequent impacts of rounding (compared to if 1 hectare was used).

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 credit requirements per hectare for each Plant Community Type and management zone could be ascertained. Credits required were then analysed separately for direct impacts, indirect impacts, cumulative impacts and rehabilitation 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 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

The direct impacts of the project require 58,813 ecosystem credits to be offset. This requirement is reduced to 24,009 ecosystem credits when areas subject to immediate rehabilitation are separated as outlined in the rehabilitation section below.

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.

Indirect impacts have only been assessed as functioning over a 30 year period while the project is in operation. This allows for the operation of particular 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. In order to quantify the contribution that the duration of indirect impacts plays on the offset liability, indirect impacts were multiplied by 0.3 to determine the final number of credits required (based on the proportion of 30 out of 100 years as a surrogate for in-perpetuity as defined by the OEH credit additionality position paper).

Indirect impacts require an additional 3,366 ecosystem credits to be offset.

For cumulative impacts, only those impacts relating to existing exploration and appraisal infrastructure which are likely to be utilised as part of the project (totalling approximately 84.8 ha) were included in the assessment. This was calculated as approximately 50% of the cumulative impact to date (excluding derived native grassland). Cumulative impacts require an additional 5,233 ecosystem 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), 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 traditional 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 this unique method of 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. Those areas subject to immediate rehabilitation following construction require 23,505 ecosystem credits, which reduces the overall offset requirement for directly impacted areas by 19.2%.

Summary of ecosystem credit requirements

The results of this ecosystem credit assessment are summarised in **Table 3** which indicate that a total of 53,009 ecosystem credits are required to meet the outcomes of the Framework for Biodiversity Assessment. Using the OEH credit converter which assumes an average Biobank site will generate 9.3 credits per ha, the equivalent offset area is 6,034 ha. This equates to a 6.1:1 offset ratio against a direct impact of 988.8 hectares or a 4.8:1 offset ratio against a combined direct, indirect and cumulative impact of 1,254.7 ha.

The assessment indicates 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.

Table 3: Major Projects Assessment (Version 4.1) – Ecosystem Credits Required

VegZone	Veg code	Biometric Vegetation Type	Ancillary	Direct Impacts		Indirect Impacts		Cumulative Impacts		Rehabilitation		Total		Offset required
				Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)
1	NA219	Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	Native Vegetation	0.04	3.35	0.00	0.00	0.00	0.00	0.06	3.74	0.10	7.09	0.76
2	NA219	Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	DNG	0.19	6.88	0.00	0.00	0.00	0.00	0.31	8.01	0.50	14.89	1.60
3	NA117	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	Native Vegetation	7.30	475.74	3.90	76.25	5.10	332.37	12.00	532.92	28.30	1,417.28	152.40
4	NA117	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	DNG	13.95	505.13	0.00	0.00	0.00	0.00	23.25	600.55	37.20	1,105.68	118.89
5	NA102	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	Native Vegetation	1.48	78.47	0.80	12.72	0.00	0.00	2.43	80.70	4.71	171.89	18.48
6	NA102	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	DNG	0.64	23.17	0.00	0.00	0.00	0.00	1.06	27.38	1.70	50.55	5.44
7	NA179	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	Native Vegetation	18.85	1,239.95	8.19	161.62	2.90	190.76	21.95	980.95	51.89	2,573.28	276.70
8	NA179	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	DNG	3.30	75.27	0.00	0.00	0.00	0.00	5.50	80.36	8.80	155.63	16.73
9	NA121	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	Native Vegetation	7.38	265.31	4.00	43.14	0.00	0.00	12.13	270.38	23.51	578.83	62.24
10	NA141	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South Bioregion (including Pilliga) and Nandewar Bioregion	Native Vegetation	2.35	182.36	1.23	28.63	0.90	69.84	3.55	201.75	8.03	482.58	51.89
11	NA141	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South Bioregion (including Pilliga) and Nandewar Bioregion	DNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	NA292	Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern Brigalow Belt South Bioregion	Native Vegetation	0.11	5.17	0.10	1.41	0.00	0.00	0.19	6.34	0.40	12.92	1.39
13	NA279	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	Native Vegetation	12.60	784.48	6.80	127.01	0.70	43.58	20.70	865.67	40.80	1,820.74	195.78
14	NA279	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	DNG	0.15	3.42	0.00	0.00	0.00	0.00	0.25	3.65	0.40	7.07	0.76
15	NA314	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	Native Vegetation	135.26	8,157.53	63.35	1,146.19	59.70	3,600.51	188.14	7,501.14	446.45	20,405.37	2,194.13
16	NA314	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	DNG	1.46	33.30	0.00	0.00	0.00	0.00	2.44	35.65	3.90	68.95	7.41
17	NA255	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	Native Vegetation	1.60	95.68	0.66	11.84	3.10	185.38	1.80	73.66	7.16	366.56	39.41
18	NA255	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion	DNG	0.08	1.82	0.00	0.00	0.00	0.00	0.13	1.90	0.21	3.72	0.40
19	NA307	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, Brigalow Belt South	Native Vegetation	0.60	31.50	0.30	4.73	0.00	0.00	1.00	32.05	1.90	68.28	7.34

VegZone	Veg code	Biometric Vegetation Type	Ancillary	Direct Impacts		Indirect Impacts		Cumulative Impacts		Rehabilitation		Total		Offset required
				Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)	# Credits	Area (ha)
		Bioregion												
20	NA307	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, Brigalow Belt South Bioregion	DNG	0.60	13.69	0.00	0.00	0.00	0.00	1.00	14.61	1.60	28.30	3.04
21	NA294	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	Native Vegetation	1.03	64.13	0.50	9.34	0.70	43.58	1.68	71.35	3.91	188.40	20.26
22	NA324	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	Native Vegetation	0.38	22.67	0.20	3.58	2.90	173.01	0.63	24.30	4.11	223.56	24.04
23	NA324	Poplar Box - White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, Brigalow Belt South Bioregion	DNG	0.49	11.18	0.00	0.00	0.00	0.00	0.81	11.83	1.30	23.01	2.47
24	NA338	Rough-barked Apple - Blakely's Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	Native Vegetation	19.10	1,353.43	9.22	196.00	3.10	219.67	27.30	1,376.19	58.72	3,145.28	338.20
25	NA338	Rough-barked Apple - Blakely's Red Gum - Black Cypress Pine woodland on sandy flats, mainly in the Pilliga Scrub region	DNG	6.79	154.88	0.00	0.00	0.00	0.00	11.31	165.24	18.10	320.12	34.42
26	NA326	Red Ironbark - White Bloodwood +/- Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	Native Vegetation	32.76	2,244.72	17.60	361.79	3.60	246.67	53.84	2,588.09	107.80	5,441.26	585.08
27	NA390	White Bloodwood - Red Ironbark - Black Cypress Pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	Native Vegetation	103.54	6,446.40	48.46	905.14	1.40	87.16	143.56	6,096.99	296.96	13,535.69	1,455.45
28	NA390	White Bloodwood - Red Ironbark - Black Cypress Pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	DNG	0.71	16.20	0.00	0.00	0.00	0.00	1.19	17.39	1.90	33.58	3.61
29	NA389	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	Native Vegetation	26.10	1,512.76	14.00	243.43	0.70	40.57	42.90	1,609.61	83.70	3,406.37	366.28
30	NA409	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, Brigalow Belt South Bioregion	Native Vegetation	0.08	5.14	0.10	1.93	0.00	0.00	0.13	5.81	0.31	12.87	1.38
31	NA409	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, Brigalow Belt South Bioregion	DNG	0.11	2.51	0.00	0.00	0.00	0.00	0.19	2.78	0.30	5.29	0.57
32	NA363	Spur-wing Wattle heath on sandstone substrates in the Goonoo - Pilliga forests, Brigalow Belt South Bioregion	Native Vegetation	3.18	193.03	1.70	30.96	0.00	0.00	5.23	213.96	10.11	437.94	47.09
				402.21	**24,009.25**	**181.11**	**3,365.70**	**84.80**	**5,233.11**	**586.66**	**23,504.92**	**1,254.78**	**56,112.98**	**6,033.65**

2.3.3 Species credits

Four 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 4** and **Table 5**). Credits required for flora species range from 42 to 144,326 credits. Credits required for fauna species range from 2,712 to 34,994 credits. *Bertya opponens* 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.

Table 4: Major Projects Assessment (Version 4.1) – Flora Species Credits Required

Species	TS offset multiplier	Direct and indirect impacts impact (# individuals)	Cumulative impact (# individuals)	Credits	Credits/ plant
Bertya opponens	1.4	10,309		144,326	14.00
Diuris tricolor	1.3	52		676	13.00
Lepidium aschersonii	1.4	3		42	14.00
Lepidium monoplocoides	1.5	4		60	15.00
Polygala linariifolia	1.5	252		3,780	15.00
Pomaderris queenslandica	1.5	467		7,005	15.00
Pterostylis cobarensis	1.3	7,364	706	95,732	13.00
Rulingia procumbens	1.5	3,716		55,740	15.00
Tylophora linearis#	7.7	479	81	36,883	77.00

#The status and offset multiplier for *Tylophora linearis* is currently under review by OEH. Should the offset multiplier be reduced, then the resulting offset liability will also be reduced.

Table 5: Major Projects Assessment (Version 4.1 – Fauna Species Credits Required

Species	Common name	Tg value	Direct impact (ha)	Indirect impact (ha)	Cumulative impact (ha)	Credits	Credits/ ha
Macropus dorsalis	Black-striped Wallaby	2.6	988.80	181.11	84.80	32,622	26.00
Cercartetus nanus	Eastern Pygmy-possum	2	774.80	153.01	76.80	20,092	20.00
Hoplocephalus bitorquatus	Pale-headed Snake	3.3	885.00	175.41	84.80	37,792	33.00
Petaurus norfolcensis	Squirrel Glider	2.2	861.80	170.71	84.80	24,581	22.00

2.3.4 Hollow-bearing trees

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

2.3.5 Assumptions and limitations

- 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.
- Due to access restrictions, no plot data was available for *NA219 Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion* and benchmark plot data was used as a surrogate.
- There was insufficient plot data for some derived native grassland (DNG) zones and all plots in derived native grassland (n=15) were pooled and entered against each derived native grassland zone.
- No plots were surveyed in *NA294 Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the Brigalow*. This vegetation type was included in a broader Biometric Vegetation Types (October 2008) which was subsequently split in the update to Namoi CMA vegetation types (October 2014). To account for this, vegetation plot data from NA279, NA326, NA390 and NA389 (previously pooled types) were pooled and entered against this vegetation zone.
- 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 MNES, 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 measureable environmental gain for the impacted protected matter. A conservation gain 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 DotE 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 MNES 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 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.
- 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 Biobanking 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 will be investigated post submission of the Environmental Impact Statement. This process will seek to meet the majority of the like-for-like offset liability of the project as far as practicable. This process will include:

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 area.

This process will 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 (including large hollow-bearing trees), identifying Aboriginal cultural heritage values, and where cost effective management can be implemented to improve the overall conservation value of the land.

Wherever possible, 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).

3.2 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 (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, 2015), species profiles and threats database (DotE, 2014) 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 TSC 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 6** for fauna and **Table 7** for flora, along with the corresponding management action to address each threat. Also included are the listed key threatening processes under TSC 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 6: Threatening processes – fauna

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: TSC 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 (*Sus scrofa*) Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*) Competition and habitat degradation by feral goats (*Capra hircus*)	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 (*Vulpes vulpes*) Predation by the feral cat (*Felis catus*) Predation and hybridisation of feral dogs (*Canis lupus familiaris*)	Predation by European red fox Predation by feral cats
Weed invasion				
19	35.1%	Weed management	Invasion of native plant communities by African Olive *Olea europaea* subsp. *cuspidata*	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants,

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: TSC Act	Equivalent Key Threatening Processes: EPBC Act
			Invasion, establishment and spread of *Lantana camara* 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	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 7: Threatening processes – flora

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: TSC Act	Equivalent Key Threatening Processes: EPBC Act
Weed invasion				
12	75%	Weed control	Invasion of native plant communities by African Olive *Olea europaea* subsp. *cuspidata* Invasion, establishment and spread of *Lantana camara* 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	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
Grazing/ habitat disturbance by herbivores				
Specific threat: Stock/ unspecified (10); pigs (5); rabbits (7); goats (5) **Overall# (12)**	62.5%	Feral herbivore control	Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*) Competition and habitat degradation by feral goats (*Capra hircus*)	Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs Competition and land degradation by rabbits Competition and land degradation by unmanaged goats

Number of species impacted	% of total species	Management action	Equivalent Key Threatening Processes: TSC Act	Equivalent Key Threatening Processes: EPBC Act
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 animcals 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.

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 8**).

Table 8: 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	*Eragrostis curvula* (African Lovegrass), *Hyparrhenia hirta* (Coolatai Grass), *Panicum maximum* (Green Panic),	Bush Stone-curlew, Speckled Warbler, Hooded Robin, Turquoise Parrot, Barking Owl, Scarlet Robin, Grey-crowned Babbler, Diamond Firetail	*Polygala linariifolia, Lepidium monoplocoides, Myriophyllum implicatum, Lepidium aschersonii*	Widespread *E. curvula* abundance observed to be increasing along edge of X-line Road	-	-
Berry-bearing shrubs	*Lycium ferocissimum* (African Boxthorn)	Scarlet robin, Diamond Firetail	*Lepidium aschersonii, Lepidium monoplocoides*	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	*Xanthium occidentale*	-	-	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
Opuntia spp.	*Opuntia stricta* (Prickly Pear), *Opuntia aurantiaca* (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	*Phyla canescens* (Lippia)	-	*Myriophyllum implicatum*	Only recorded at one location, however this location is within 1 km of the *M. implicatum* 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 opponens, 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. 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).

<u>Feral Fox control</u>

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 9: 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).	
	Grampians NP	1.10	Pulse of 6-8 weeks baiting,	

Method	Location	Cost per ha ($)	Details of program	Reference
	Victoria (72520 ha)		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 Eradicat® 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 Eradicat® 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 10: 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/km^2 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/km^2 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 11: 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 12: 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 8**, the cost of treatment per hectare shows extreme variability. For example, the cost of controlling Opuntioid cacti species by spraying with herbicides can range from a few hundred dollars to $8,000 or more per hectare (Lloyd & Reeves, 2014). **Table 13** 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 13: 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/ fluproponate	>$360	Pasture, North West Slopes NSW	(McCormick, L., Lodge, & McGullicke, 2002)
	Fluproponate	<$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)
Opuntia spp.	Spot spraying/ digging out	<$100 chemical cost + $100-249 labour costs Total ~$349	NSW	(DPI, 2014)

Weed Species	Control method	Cost per ha	Details and location	Reference
	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 14**. 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 14: 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)
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	(Scherl, 2005)

Location	Purpose of burning	Cost per ha ($)	Notes on figure given	Reference
			Figures include staff and resourcing costs.	

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 approximately equivalent to one third of the total 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.

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). 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 offset fund or bond

Once land-based offsets and supplementary measures have been finalised, the remaining offset liability for the project will be converted into a dollar figure and held for eventual transfer into the Biodiversity Offset Fund (once established).

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

The Biodiversity Offset Fund will then be used by the fund program manager (NSW Government or others) 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*.

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 Offsets Fund for Major Projects 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 (including 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 Biobanking Assessment Methodology.
- Prepare a nil-tenure feral animal control strategy which will be approximately equivalent 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 Biobanking Assessment Methodology.
- Undertake a periodic review of the Biodiversity Offset Management Plan every 5 years in accordance with the Biobanking Assessment Methodology.

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Appendix A Culturally important food plants

Scientific Name	Common Name/s	Use
Acacia farnesiana	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.
Ajuga australis	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
Allocasuarina diminuta	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 Wyrie Swamp, South Australia.
Alphitonia excelsa	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 relive 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.
Alstonia constricta	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
Amyema miquelii	Drooping mistletoe, stalked mistletoe, snotty gobbles, boxed mistletoe	Edible fruit, Mrs Jean Hamilton grew up at Cuttabri and around Pilliga and she remembers collecting snottygobbles from different trees. Mr Dan Trindall and Mrs Delma Brennan during the oral histories told how they used to get snottygobbles off the vines on horseback, it made it easy to reach the fruit off the horses. Delma described snottygobbles as a thing that was full of

Scientific Name	Common Name/s	Use
		moisture
Astrebla pectinata	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
Astroloma humifusum	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
Banksia marginata	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.
Brachychiton populneus	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.
Calandrinia eremaea	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
Callitris glaucophylla	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 *Callitris* 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.
Capparis lasiantha	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
Capparis mitchellii	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 Minnon Mission at Pilliga. Mrs Mavis Dennison grew up at Old Toomelah and she described the bumble like an apple or orange and very tasty.
Cassytha glabella	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
Centipeda cunninghamii	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
Chenopodium cristatum	Crested crumbweed, crested goose floot	Poultice of leaf and stem were applied for septic inflammation and breast abscess
Citrullus colocynthis	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
Dodonaea viscosa	Giant hopbush, watchupga, switch-sorrel, sticky hopbush, akeake, apiri, hopbush	Cochrane *et al.* (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.
Enchylaena tomentosa	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
Eucalyptus camaldulensis	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 scares are still present to this day

Scientific Name	Common Name/s	Use
Eucalyptus populnea	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
Exocarpos cupressiformis	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
Flindersia maculosa	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
Geijera parviflora	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
Grevillea striata	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
Hakea leucoptera	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
Indigofera australis	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
Lomandra longifolia	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
Macrozamia heteromera	Commentary applies to this and following Macrozamia species found in the Southern Brigalow Belt	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 et al). 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 leeched 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 leeched 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.
Marsilea drummondii	Nardoo, Southern cross	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 produce damper or porridge. Usually made when food was scarce or in hard times such as

Scientific Name	Common Name/s	Use
		drought.
Mentha satureioides	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
Myoporum montanum	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
Opuntia stricta	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
Owenia acidula	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.
Persoonia spp. (*curvifolia, sericea* and *cuspidifera*)	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
Phragmites australis	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
Pimelea linifolia	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
Pittosporum phylliraeoides	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.
Portulaca oleracea	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 god source of minerals European settlers believed it to cure scurvy, resent 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
Santalum acuminatum	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
Sarcostemma australe	Caustic bush, milk bush, tableland caustic bush, caustic plant, ley bush, snake plant, milk vine, pencil caustic, snake vine	A rubbing medicine. *Kiji kiji* 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
Sonchus oleraceus	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 later the ground was bare of thistles, and the tribe passed on gratefully devouring the juicy

Scientific Name	Common Name/s	Use
		weed."
Styphelia triflora	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.
Themeda spp. (*australis* and *avenacea*)	Kangaroo grass	The seeds are ground and baked. A closely related species, Themeda avenacea 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
Thysanotus tuberosus	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
Typha orientalis	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 the stems in an earth oven. After steaming, the stems they were chewed removing starch and the

Scientific Name	Common Name/s	Use
		remaining fibre was used to make the string.
Urtica incisa	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
Xanthorrhoea australis	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 (Xanthorrhoea australis) was used serving as a base in which a stem of Austral Mulberry (Hedycarya angustifolia) 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 15 to **Table 18** 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 15: Threats to threatened fauna species known or with the potential to occur in the study area

Scientific name	Common name	TSC 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				
Aepyprymnus rufescens	Rufous Bettong	V	~	P	1	1	1	1				2	1	2	1			1				1		(OEH, 2015); (Kavanagh & Stanton, 2005)
Anseranas semipalmata	Magpie Goose	V	Mar	P	1	1				1		1		1	1									(OEH, 2015); (DotE, 2014)
Anthochaera phrygia	Regent Honeyeater	CE	E, M	P	1	2	1					1	1		1			1			1	1		(ACT Government, 1999b), (OEH, 2015), (DECCW, 1999)
Apus pacificus	Fork-tailed Swift	-	M, Mar	K	1		1																	(DotE, 2014)
Ardea alba	Great Egret, White Egret	~	M, Mar	K								1		1										(DotE, 2014)
Ardea ibis	Cattle Egret	~	M, Mar	K	1		1																	(DotE, 2014)
Ardeotis australis	Australian Bustard	E1	~	P	1	1	1					2			1		1		1					(OEH, 2015)
Botaurus poiciloptilus	Australasian Bittern	E1	E	P	1	1	1	1				1			1	1								(OEH, 2015); (DotE, 2014)
Burhinus grallarius	Bush Stone-curlew	E1	~	P	1	1	1	1				1		1	1		1					1		(OEH, 2015); (DEC, 2006b)
Calidris acuminata	Sharp-tailed Sandpiper		M, Mar	P										1										
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	~	K							1	1			1	1								(OEH, 2015)
Cercartetus nanus	Eastern Pygmy-possum	V	~	K	1	1	1	1				1			1			1				1		(OEH, 2015)
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	P	1	1						1			1				1					(OEH, 2015); (DotE, 2014)
Chalinolobus picatus	Little Pied Bat	V	~	K	1		1																	(OEH, 2015)
Chthonicola	Speckled Warbler	V	~	K	1	1	1	1	1			1		1	1			1				1		(OEH, 2015)

Scientific name	Common name	TSC 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				
sagittata																								
Circus assimilis	Spotted Harrier	V	~	K											1									(Attwood et al., 2009)
Daphoenositta chrysoptera	Varied Sittella	V	~	K										2							1	1		(OEH, 2015)
Dasyurus maculatus	Spotted-tailed Quoll	V	E	P	1	1	1	1				1		1	1							1		(DECCW, 2010); (OEH, 2015); (TSSC, 2004)
Ephippiorhynchus asiaticus	Black-necked Stork	E1	~	K										2	2									(OEH, 2015)
Falco hypoleucos	Grey Falcon	E1	~	P											1									(OEH, 2015)
Falco subniger	Black Falcon	V	~	K											1									(NSW Scientific Committee, 2013)
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	~	M, Mar	P	1	1							1		1									(DotE, 2014)
Glossopsitta pusilla	Little Lorikeet	V	~	K							1	2												(OEH, 2015)
Grantiella picta	Painted Honeyeater	V	~	K											1			1						(DSE, 2003a); (OEH, 2015)
Grus rubicunda	Brolga	V	~	P	1	1						1			1									(DSE, 2003b)
Haliaeetus leucogaster	White-bellied Sea-Eagle	~	M, Mar	K																				
Hamirostra melanosternon	Black-breasted Buzzard	V	~	P											1									(OEH, 2015)
Hieraaetus morphnoides	Little Eagle	V	~	K											1							2		(OEH, 2015)
Hirundapus caudacutus	White-throated Needletail	-	M, Mar	K																				
Hoplocephalus bitorquatus	Pale-headed Snake	V	~	K								1			2							1		(OEH, 2015)

Scientific name	Common name	TSC 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				
Lathamus discolor	Swift Parrot	E1	E, Mar	P	1		1				1	1			1						1			(DotE, 2014);
Lophoictinia isura	Square-tailed Kite	V	~	K								1			1									(OEH, 2015)
Macropus dorsalis	Black-striped Wallaby	E1	~	K	1	1	1					1		1	1			1	1					(OEH, 2015)
Melanodryas cucullata cucullata	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)
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	~	K											1						1			(OEH, 2015)
Merops ornatus	Rainbow Bee-eater	~	M, Mar	K	1	1		1																(DotE, 2014)
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	~	K	1	1	1					1		1										(OEH, 2015)
Myiagra cyanoleuca	Satin Flycatcher	~	M, Mar	K																				
Neophema pulchella	Turquoise Parrot	V	~	K	1	1	1				1			1	1		2		2					(OEH, 2015)
Ninox connivens	Barking Owl	V	~	K	1	1	1				1	1	1	1	1							1		(OEH, 2015); (NPWS, 2003)
Nyctophilus corbeni (syn. Nyctophilus timoriensis (South-eastern form))	South-eastern Long eared Bat / Corben's Long-eared Bat	V	V	K						1	1	1			1			1						(DotE, 2014)
Oxyura australis	Blue-billed Duck	V	~	P	1	2						1			1									(OEH, 2015)
Pachycephala	Gilbert's Whistler	V	~	P								1			1									(OEH, 2015)

Scientific name	Common name	TSC 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				
inornata																								
Petaurus norfolcensis	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)
Petroica boodang	Scarlet Robin	V	~	P			1		1			2	1	1	1							1		(OEH, 2015)
Phascolarctos cinereus	Koala	V	V	K				1				1		1	1									(DECC, 2008); (OEH, 2015); (Woinarski et al., 2014)
Polytelis swainsonii	Superb Parrot	V	V	P	1	1	1				1	1			1								1	(ACT Government, 1999c); (OEH, 2015); (Baker-Gabb, 2011)
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V	~	K	1	1	1							1	1						1	1		(DSE, 2001); (OEH, 2015)
Pseudomys pilligaensis	Pilliga Mouse	V	V	K	1	1	1		1			1					1							(DotE, 2014); (OEH, 2015)
Rostratula australis (syn. Rostratula benghalensis australis)	Australian Painted Snipe	E1	E, Mar	P	1	1	1	1				1		1	1									(DotE, 2014); (OEH, 2015)
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	~	K							1													(OEH, 2015)
Scoteanax rueppellii	Greater Broad-nosed Bat	V	~	K							1	1												(OEH, 2015); (Woinarski et al., 2014)
Sminthopsis macroura	Stripe-faced Dunnart	V	~	P	1	1	1					1			1		2	2	2			1		(OEH, 2015)
Stagonopleura guttata	Diamond Firetail	V	~	K								1		1	1			1				1		(OEH, 2015)

Scientific name	Common name	TSC 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				
Stictonetta naevosa	Freckled Duck	V	~	P						2		2			1		2		2					(OEH, 2015)
Tyto novaehollandiae	Masked Owl	V	~	K	1	1					1	1	1		1							1		(DEC, 2006b);(DSE, 2003c); (OEH, 2015)
Vespadelus troughtoni	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 16: Management actions that benefit threatened fauna species known or with the potential to occur in the study area

Scientific name	Common name	TSC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock exclusion	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/placement woody debris	Info sources
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses				
Aepyprymnus rufescens	Rufous Bettong	V	~	P	1	1	2				1		1	1		1							1	(OEH, 2015)
Anseranas semipalmata	Magpie Goose	V	Mar	P	2				1		1		1	1										(OEH, 2015)
Anthochaera phrygia	Regent Honeyeater	CE	E, M	P	1	1					1			1			1					1	2	(OEH, 2015); (QLD EPA, 2008)
Apus pacificus	Fork-tailed Swift	-	M, Mar	K		2																		
Ardea alba	Great Egret, White Egret	~	M, Mar	K							2		2											
Ardea ibis	Cattle Egret	~	M, Mar	K		2																		
Ardeotis australis	Australian Bustard	E1	~	P	1	1					1			1	1		1		1					(OEH, 2015)
Botaurus poiciloptilus	Australasian Bittern	E1	E	P	1	1	2				1			1	1	2								(OEH, 2015)
Burhinus grallarius	Bush Stone-curlew	E1	~	P	1	1	1				2		1	1	1							1	1	(OEH, 2015); (DEC, 2006a)
Calidris acuminata	Sharp-tailed Sandpiper		M, Mar	P									2											(DotE, 2014)
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	~	K						1	1			1										(OEH, 2015)
Cercartetus nanus	Eastern Pygmy-possum	V	~	K	1	1	1				1			1									1	(OEH, 2015)
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	P	1						1			1					1					(OEH, 2015)
Chalinolobus picatus	Little Pied Bat	V	~	K		1																		(OEH, 2015)
Chthonicola sagittata	Speckled Warbler	V	~	K	1	1					2		2	1	1			2					1	(OEH, 2015)
Circus assimilis	Spotted Harrier	V	~	K										1										(OEH, 2015)
Daphoenositta chrysoptera	Varied Sittella	V	~	K									1	1									1	(OEH, 2015)
Dasyurus maculatus	Spotted-tailed Quoll	V	E	P	1	1	2				1		2	2										(ACT Government, 2005), (OEH, 2015)

Scientific name	Common name	TSC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock exclusion	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/placement woody debris	Info sources
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses				
Ephippiorhynchus asiaticus	Black-necked Stork	E1	~	K									1	1										(OEH, 2015)
Falco hypoleucos	Grey Falcon	E1	~	P										1										(OEH, 2015)
Falco subniger	Black Falcon	V	~	K										2										
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	~	M, Mar	P	2							2		2										
Glossopsitta pusilla	Little Lorikeet	V	~	K							1													(OEH, 2015)
Grantiella picta	Painted Honeyeater	V	~	K										1				2						(OEH, 2015)
Grus rubicunda	Brolga	V	~	P	1						2			1										(DSE, 2003b); (OEH, 2015)
Haliaeetus leucogaster	White-bellied Sea-Eagle	~	M, Mar	K																				
Hamirostra melanosternon	Black-breasted Buzzard	V	~	P										1									1	(OEH, 2015)
Hieraaetus morphnoides	Little Eagle	V	~	K																				
Hirundapus caudacutus	White-throated Needletail	-	M, Mar	K																				
Hoplocephalus bitorquatus	Pale-headed Snake	V	~	K							1			1									2	
Lathamus discolor	Swift Parrot	E1	E, Mar	P		2					2			1										(DotE, 2014); (Swift Parrot Recovery Team, 2011)
Lophoictinia isura	Square-tailed Kite	V	~	K							1			2										
Macropus dorsalis	Black-striped Wallaby	E1	~	K	1	1					1		1	1				1	1					
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V	~	K	2	2	2				2		2	1									1	(OEH, 2015)
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	~	K										2										(OEH, 2015)
Merops ornatus	Rainbow Bee-eater	~	M, Mar	K	2		2																	(DotE, 2014)

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

Scientific name	Common name	TSC Act status	EPBC Act status	Likelihood of occurrence	Feral predator control					Nest box supplementation	Fire management	Ecological thinning	Weed control	Grazing management/ stock exclusion	Fenced refugia	Feral herbivore control					Removal of feral bees	Captive breeding	Retention/placement woody debris	Info sources
					Foxes	Cats	Wild dogs	Rats/Mice	Unspecified							Unspecified	Pigs	Rabbits	Goats	Horses				
Stictonetta naevosa	Freckled Duck	V	~	P					1		1			1			1		1					(OEH, 2015)
Tyto novaehollandiae	Masked Owl	V	~	K	2						2	2		2									2	
Vespadelus troughtoni	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 17: Threats to threatened flora species known or with the potential to occur in the study area

Scientific name	Common name	TSC 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	
Bertya opponens	Coolabah Bertya	V	V	K	1		1				1		(DotE, 2014); (OEH, 2015)
Cyperus conicus	A sedge	E1	~	P				1		1			(OEH, 2015)
Desmodium campylocaulon	Creeping Tick-Trefoil	E1	~	P				1					(OEH, 2015)
Dichanthium setosum	Bluegrass	V	V	P	1		1	1		2			(DotE, 2014); (OEH, 2015)
Digitaria porrecta	Finger Panic Grass	E1		P	1		1	1					(OEH, 2015)
Diuris tricolor	Painted Diuris	V	~	K			1			1	1		(OEH, 2015)
Homopholis belsonii	Belson's Panic	E1	V	P		1	1	1					(DotE, 2014); (OEH, 2015)
Lepidium aschersonii	Spiny Peppercress	V	V	K			1	1	1	1			(DotE, 2014); (OEH, 2015)
Lepidium monoplocoides	Winged Peppercress	E1	E	K			1	1	1	1			(DotE, 2014); (OEH, 2015)
Monotaxis macrophylla	Large-leafed Monotaxis	E1	~	P	1								(OEH, 2015)
Myriophyllum implicatum		CE	~	K			1		1				(OEH, 2015)
Polygala linariifolia	Native Milkwort	E1	~	K	1		1	1		1	1		(OEH, 2015)
Pomaderris queenslandica	Scant Pomaderris	E1	~	K	1		1						(OEH, 2015)
Pterostylis cobarensis	Greenhood Orchid	V	~	K			1	1	1	1	1		(OEH, 2015)
Rulingia procumbens		V	V	K	1	1							(OEH, 2015)
Tylophora linearis	-	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 18: Management actions that benefit threatened flora species known or with the potential to occur in the study area

Scientific name	Common name	TSC 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	
Bertya opponens	Coolabah Bertya	V	V	K	1		1					1		(DotE, 2014); (OEH, 2015)
Cyperus conicus	A sedge	E1	~	P				2			2			(OEH, 2015)
Desmodium campylocaulon	Creeping Tick-Trefoil	E1	~	P				1	1					(OEH, 2015)
Dichanthium setosum	Bluegrass	V	V	P	1		1	1			1			(DotE, 2014); (OEH, 2015)
Digitaria porrecta	Finger Panic Grass	E1		P	1		2	1						(OEH, 2015)
Diuris tricolor	Painted Diuris	V	~	K			2				2	2		(OEH, 2015)
Homopholis belsonii	Belson's Panic	E1	V	P			1	1						(DotE, 2014); (OEH, 2015)
Lepidium aschersonii	Spiny Peppercress	V	V	K			1	1		1	1			(Carter, 2010); (DotE, 2014); (OEH, 2015)
Lepidium monoplocoides	Winged Peppercress	E1	E	K			1	1		2	1			(DotE, 2014); (Mavromihalis, 2010); (OEH, 2015)
Monotaxis macrophylla	Large-leafed Monotaxis	E1	~	P	1									(OEH, 2015)
Myriophyllum implicatum		CE	~	K			1			1				(OEH, 2015)
Polygala linariifolia	Native Milkwort	E1	~	K	1		1	1			1	1		(OEH, 2015)
Pomaderris queenslandica	Scant Pomaderris	E1	~	K	1		1							(OEH, 2015)
Pterostylis cobarensis	Greenhood Orchid	V	~	K			1	1	1	2	2	2		(OEH, 2015)
Rulingia procumbens		V	V	K	1	1								(OEH, 2015)
Tylophora linearis	-	V	E	K	1		1	1		2		2		(NSW Scientific Committee, 2008c); (OEH, 2015); (TSC, 2008)

Scientific name	Common name	TSC 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
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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 (RGb-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 RG-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).

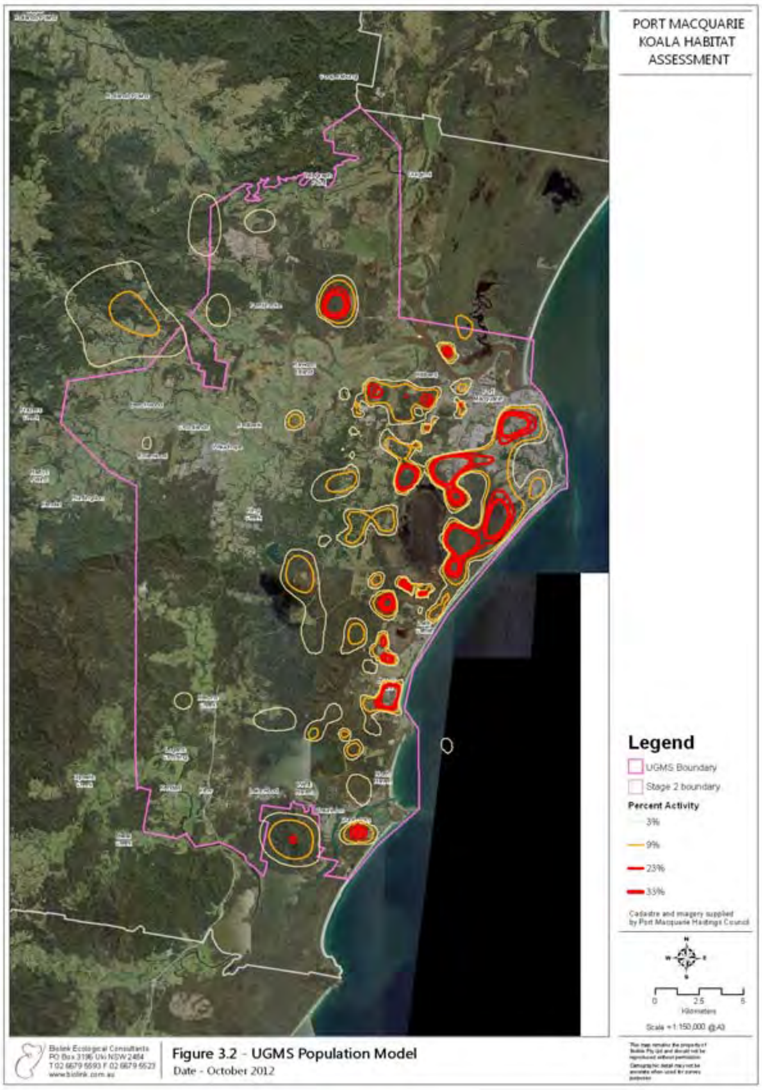

Figure 1. Koala meta-population model for a 74,000 ha coastal portion of the Port Macquarie Hastings Local Government area on the mid-north coast of NSW. The model was based on interpolation of koala activity data collected using the RG-bSAT approach with sampling intervals of 250 m – 1000 m. Across 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.

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Appendix M: Compliance with the NSW Biodiversity Offsets Policy for Major Projects

Stage 1 – Biodiversity assessment requirements	Report section
1 Matters relating to the biodiversity assessment requirement	
1.1 Format and content of the biodiversity assessment report	
Stage 1: Biodiversity assessment requirement	
(a) A set of maps of the proposed development site that:	
(i) identifies the development footprint, including areas of ‘temporary’ clearing, associated with construction as assessed and determined by the assessor in accordance with Section 6	Section 4.11
(ii) shows the extent and distribution of PCTs and vegetation zones that, in the opinion of the assessor are present on the proposed development site, including the locations of plot and transect surveys	Section 5.3.1, Figure 5 and Figure 15
(iii) shows the extent and distribution of endangered ecological communities and critically endangered ecological communities that, in the opinion of the assessor, are present on the development site	Section 5.3.2 and Figure 17
(iv) identifies the IBRA subregion/s and Mitchell landscape/s in which the development is located	Figure 2 and Figure 4
(v) shows the location of any threatened species that, in the opinion of the assessor, cannot withstand further loss	Appendix J and Appendix K assess the impact of the project on threatened species
(vi) shows the location of other threatened species and their habitat that, in the opinion of the assessor, are present on the site (Section 5.3), including location of surveys used to assess the development site	Figures 5-12, 13, 14 and 18
(vii) identifies areas on the development site where an offset is not required as assessed and determined in accordance with Section 7.2.	Figure 15 (‘other’), Table 33
Note: All maps must include: map title, the site’s name, location and lot/DP numbers, scale and grid reference, the date the map was prepared and a legend	All figures
(b) a description of the vegetation classification used by the assessor, the assessor’s justification on the choice of PCTs, identification of the native plant species determined by the assessor to be present and a description of the mapping and survey techniques used to survey the development site (Section 3.3 and Section 3.4)	Section 4, Appendix F2, Appendix B and Appendix C
(c) a description of the Site value (condition) of the PCTs determined by the assessor to be present	Appendix D

Stage 1 – Biodiversity assessment requirements	Report section
(d) a description of the landscape value of the development site as assessed by the assessor in accordance with Section 4, and the method used by the assessor to assess landscape value	Appendix L
(e) a description of threatened species that, in the opinion of the assessor, are present at the development site. This description must include:	Section 5.3.4, Section 5.4.2,
(i) identification of threatened species habitat for species assessed by the assessor for ecosystem credits, including reasons that justify when a predicted species is assessed in accordance with Section 5.2 by the assessor as not being present on the development site	Section 4.5 and Section 4.6
(ii) identification by the assessor of any breeding habitat features for species that require ecosystem credits	Section 4.6
(iii) identification by the assessor of the species assessed in accordance with Section 5.3 for species credits and justification for why a species is removed from the candidate list	Appendix L
(iv) a description of the survey techniques, timing and effort used by the assessor to assess threatened species in accordance with Section 5.4	Section 4.4 to 4.8
(v) results of the targeted threatened species survey including the area and location of the species identified by the assessor and undertaken in accordance with Section 5.3	Section 5.3 and Section 5.4
(vi) identification of any threatened species that cannot withstand further loss	Appendix J and Appendix K assess the impact of the project on threatened species
(vii) expert reports used in the assessment of threatened species and prepared in accordance with Section 5.5	Not applicable
(f) any expert reports used for the assessment of biodiversity values on the development site and prepared in accordance with Section 5.5	Not applicable
(g) justification of the assessor’s use of certified local data in accordance with Section 13.2 for any part of the assessment of biodiversity values on the development site.	Not applicable
Stage 2: Impact assessment on biodiversity values	
(a) Define the circumstances where a full assessment of the impact on biodiversity values is not required (Section 2.2)	Not applicable

Stage 1 – Biodiversity assessment requirements	Report section
(b) circumstances where, after undertaking an assessment of biodiversity values, the assessor determines that an offset is not required under Section 2.2	Not applicable
(c) a demonstration of the steps taken at the planning, construction and design phases to avoid and minimise the impacts of development (Section 6) including:	Section 6.2
(i) a description of the methods used to select a project site to ensure impacts of the development are avoided to the extent practicable or a reason for not using a method	Section 6.2
(ii) the measures that were taken, or are proposed to be taken by the proponent, to avoid and minimise the direct impacts of the development (Section 6.3)	Section 6.2
(iii) the measures that were taken, or are proposed to be taken by the proponent, to avoid and minimise the indirect impacts of the development (Section 6.4)	Section 6.2
(iv) justification for where further avoidance and minimisation of the impacts of development on biodiversity is not practicable	Not applicable
(d) assessment of the remaining adverse impacts on site value on:	
(i) ecological communities; and	Section 6.3 to 6.5
(ii) threatened species habitat as identified by the assessor (Section 7.2)	Section 6.3 to 6.5
(e) assessment of the remaining adverse impacts on landscape value (Section 7.3)	Appendix L
(f) calculation of the number of ecosystem credits for the remaining direct impacts on ecological communities and threatened species habitat (Section 7.4)	Appendix L
(g) calculation of the number of species credits for the remaining direct impacts on individual threatened species (Section 7.5)	Appendix L
(h) calculation of biodiversity credits for any indirect impacts where possible to measure (Section 7.6)	Appendix L
(i) biodiversity credit assessment report (biodiversity credits) produced from the Credit Calculator, that sets out the number and type of biodiversity credits required to offset the remaining impacts of development (Sections 7.4, 7.5 and 7.6)	Appendix L
(j) identification of any impacts on biodiversity values that require further consideration (Section 8)	Appendix J and Appendix K assess the impact of the project on threatened species

Stage 1 – Biodiversity assessment requirements	Report section
(k) any expert reports the assessor uses to assess the impact on biodiversity values at the development site	Not applicable
(l) justification of the use of local data in accordance with Section 13.2 where the assessor has used more appropriate local data in any part of the impact assessment on biodiversity values at the development site.	Not applicable
1.2 Circumstances where a full assessment of impacts on biodiversity values is not required	
If, during the assessment of biodiversity values at a development site, the assessor determines that:	
1.= an area of land does not contain native vegetation, then no further assessment of the impact of the development on biodiversity values is required for that area of land; and	Figure 15 ('other'), Table 33
2.= a vegetation zone has a Site value score of 17 or less, and in the opinion of the assessor, the PCT is not listed as a critically endangered or endangered ecological community under the TSC Act or EPBC Act , then: a.= assessment of native vegetation in that zone is not required beyond Section 3.4.2, and b.=assessment of threatened species habitat in that zone is not required beyond Section 5.3, and	Not applicable
3.= no threatened species or habitat components that require species credits have been identified after completing Step 3 in Section 5.3 of the FBA.	Not applicable

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