BioCondition and Habitat Quality Score Assessment Report

Surat Gas Project

PREPARED FOR ARROW ENERGY PTY LTD
September 2021

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ECOSMART ECOLOGY
48 Streeton Parade
Everton Park QLD 4053 Australia

Tel: +61 7 3162 1161

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1.0 INTRODUCTION

1.1 BACKGROUND

Arrow Energy is preparing their Offset Area Management Plan (OAMP) for the Surat Gas Project (SGP) located in the southern Brigalow Belt. To complete the plan Arrow Energy requires Regional Ecosystems (REs) within their tenements to have their 'habitat condition' evaluated for several Matters of National Environmental Significance (MNES) listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Relevant MNES which require assessment are outlined in Table 1.1.

Table 1.1. Target MNES for which habitat condition needs to be assessed

Scientific Name	Common Name	Status	
		EPBC Act	**VM/NC Act**
Threatened Ecological Communities (TEC)			
Brigalow communities (Acacia harpophylla dominant and co-dominant)		End	End
Coolibah-Black Box woodlands of the Darling Riverine Plains and the Brigalow Belt South (BBS) bioregion		End	OC
Poplar Box Grassy Woodland on Alluvial Plains**		Endangered	Of Concern
Threatened Species			
Delma torquata	Collared Delma	Vul	Vul
Anomalopus mackayi	Five-clawed Worm-skink	End	Vul
Egernia rugosa	Yakka Skink	Vul	Vul
Furina dunmalli	Dumnall's Snake	Vul	Vul
Geophaps scripta scripta	Squatter Pigeon	Vul	Vul
Anthochaerea phrygia	Regent Honeyeater	Cr End	Cr End
Grantiella picta	Painted Honeyeater	Vul	Vul
Phascolarctos cinereus	Koala	Vul	Vul
Petauroides volans	Greater Glider	Vul	Vul
Nyctophilus corbeni	Southern Long-eared Bat	Vul	Vul

CR End = Critically Endangered; End = Endangered; Vul = Vulnerable; OC = Of Concern; **Not discussed in this document

Evaluating these REs will allow Arrow Energy to estimate the value of lost habitat for which equivalent offsets must be found.

1.2 SCOPE OF WORKS

EcoSmart Ecology and 3D Environmental was engaged by Arrow Energy to assist with habitat quality assessments to meet project goals and undertook the following scope of works:

- Reassess MNES likely occurrence within the SGP area in light of additional work and data gathered since the EIS and Supplementary EIS assessments (3d Environmental 2011, 2013).
- A Review of historic BioCondition and habitat quality surveys to identify relevant data.

- A gap analysis to identify REs which have been poorly surveyed or require additional data.
- BioCondition and habitat quality assessments for REs identified as requiring additional data.
- Compile historic and contemporary BioCondition and habitat quality assessments for REs within properties provided by Arrow.
- Calculate habitat quality scores for target MNES using the compiled RE data and modelled habitats.

Offset evaluation will be undertaken in the future and, as this might be conducted by other parties, the habitat quality scoring criteria has been detailed in full. These should be reviewed prior to any future offset actions as some data is collected outside the normal Biocondition methodology.

1.3 Project Team

The survey and study team and their respective roles are detailed in Table 1.2.

Table 1.2. Project team, qualifications/experience and roles

Name	Qualifications	Experience	Role
Mark Sanders	BSc (Hons)	20+ yrs	Principle client liaison, field assessment (fauna), data entry/analysis, GIS, and reporting.
David Stanton	BSc (Hons)	20+ yrs	Data entry/analysis, GIS, and reporting
Peter Moonie	BSc	20+ yrs	Field assessment (flora), data entry
Angus McNab	BSc (hons), MSc.	10+ yrs	Field assessment (fauna), data entry

2.0 SURVEY AND STUDY METHODS

2.1 LITERATURE/DATA REVIEW AND GAP ANALYSIS

2.1.1 Literature Review

Prior to field investigations a literature review was undertaken on all target fauna species. The review focused on:

- Recent publications which might shed new light on existing fauna habitat mapping rules (i.e., habitat suitability mapping) for the SGP.
- Determining the species ecological requirements and habits with the specific aim of identifying indicators for measuring *Species Habitat Index* attributes.

2.1.2 Data Review and Gap Analysis

For this work Arrow Energy provided a list of REs, the number of habitat quality score (HQS) sites required within each RE as per the *Guide to determining terrestrial habitat quality – Version 1.3* (DES 2020), and a list of properties where further field data could be collected. Comparing this information to work completed in previous assessments (3D Environmental 2013; EcoSmart Ecology 2017, 2018, 2019a) identified the number of additional sites in each RE requiring assessment (Appendix A). Sites were selected within relevant REs to fulfill these gaps based on the properties provided by Arrow.

In total 161 BioCondition sites are required, 87 BioCondition sites were sourced from earlier assessment events leaving a balance of 74 sites for field assessment. Where representations of REs requiring assessment were not present within permitted property boundaries, additional sites were selected in publicly available easements (particularly road reserves) to supplement the field survey effort. We were unable to locate suitable sites within public easements or the supplied properties for RE11.5.21, 11.7.2, 11.7.5 and 11.7.6. No further assessment of these RE's was undertaken.

The SGP threatened fauna database was updated with records collected since the last assessment (EcoSmart Ecology 2019a) and cross-referenced against the SGP ground-verified vegetation map, or Queensland Herbarium RE Mapping (if in the surrounding area), to identify additional REs which should be added to habitat suitability mapping. This also ensures the 'core habitat known' dataset is current.

New records were attained by reinspecting existing databases (e.g., ALA), provided by Arrow from other ecological works (including spotter-catcher reports where available), or garnished from relevant public reports/papers.

2.2 FIELD SURVEY METHODOLOGY

The field survey was completed over a 12-day period from the 10th to the 21st May 2021. Survey methods were adopted from the *Guide to determining terrestrial habitat quality – Version 1.3* (DES 2020) and the *Queensland BioCondition Assessment Manual* (Eyre *et al.* 2015). BioCondition sites consisted of a 100x50 m plot in which the following parameters were measured:

- Large trees assessed against benchmark thresholds (100x50 m plot).
- Canopy cover including sub-canopy and shrub layers (measured along a 100 m plot centreline).
- Native species richness within the following plots:
  - 100x50 m for trees.
  - 50x10 m for shrubs, forbs, grasses and other life forms.
- Coarse woody debris in a 50x20 m plot.
- Groundcover composition (grass, forbs shrubs, exotics) assessed in five 1 m^2 quadrats along the transect centreline.
- Number of tree species recruiting in 100x50 m plot.

A total of 62 HQS sites were assessed with their locations shown in Figure 2.1. A breakdown of the REs assessed is provided in Table 2.1.

Table 2.1. Regional Ecosystems assessed during the current field survey for this work (see also Appendix A and Section 2.1.2).

RE	No. Sites	Site Completed
11.3.1	4	CN10, CS2, RR10-RR12
11.3.2	14	CN11, CN12, S1, CN1, RR1, RR2, RR4, RR8, S2, S3, S7, S8, CS10, CS16
11.3.3	5	CS19, CS21, CN3, CN4, CN5
11.3.4	9	CN15, CN16, CS12-CS14, CS17, CS20, RR3, CN2
11.3.14	2	CS4, CS9
11.3.17	6	CS1, CS3, RR5-RR7, RR9
11.3.17 (regrowth)	4	CS11, CS15, CN8, CN9
11.3.27f	1	S4
11.4.3	6	S6
11.5.1	1	CN13
11.5.20	4	CN7, CS5, CS6, CS7
11.5.20 (Regrowth)	1	CN14
11.5.21	2	N1, N2
11.7.4	1	CS8
11.7.6	1	CS18
11.7.7	1	N3

Habitat searches for evidence of fauna or fauna species was also undertaken during these surveys. Rocks, logs, exfoliating bark and other shelter features were shifted (where possible) in search of signs or individuals. Scat searches were undertaken in suitable Koala habitats and notes were kept of bird species heard or encountered. While these methods can locate most of the fauna species present, they are not sufficient to determine the presence/absence of a species with confidence.

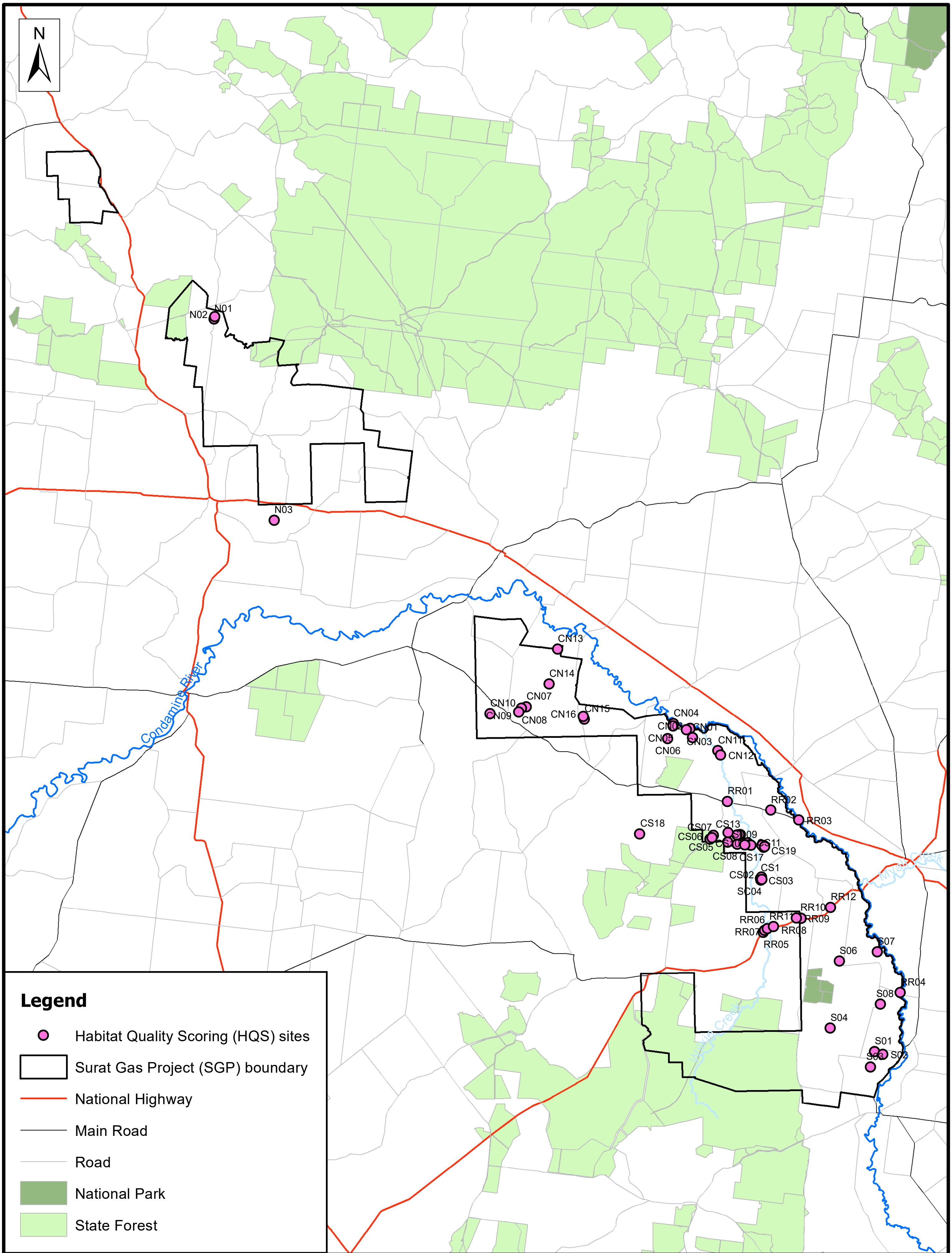

Figure 2.1

BioCondition/HQS sites assessed during field surveys in this work

Scale:

1:730,369

0 4 8 16 24 32

Kilometers

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

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2.3 Evaluating Habitat Condition

Habitat condition was evaluated by sampling a subset of RE patches within properties provided by Arrow Energy for this purpose. Evaluation used methods similar to those within the *Guide to determining terrestrial habitat quality v1.3* (DES 2020) which scores habitat quality using the three following features:

- *Site condition*: evaluates general vegetation condition compared to an undisturbed reference site with most of its natural values intact (a BioCondition benchmark).
- *Site context*: evaluates the landscape position of the site and the influence this has on the site's quality.
- *Species habitat index*: evaluates the ability of the site to support a particular species based on that species' specific habitat requirements.

With each feature scoring a maximum of 3, 3 and 4 respectively, the site is given an accumulative score out of 10 with 10 representing a fully intact and highly suitable habitat for the species/value. Scores are determined by measuring attributes collected within a 100x50m plot and containing various sub-plots, as detailed in Eyre *et al.* (2015). A brief overview of these attributes is provided below.

<u>Site Condition</u>

Site condition is measured by sampling the attributes in Table 1.1 and scored against a 'BioCondition Benchmark' for each RE provided by the Queensland Herbarium (v3.1, 2021). In this study v3.1 benchmark scores were available for all sampled REs except 11.5.1, this RE used benchmarks provided in an earlier version (2015). A final score out of 3 was attained using the following:

$$\left(\frac{Measured\ site\ condition\ score}{Maximum\ (benchmark)\ condition\ score}\right)x3$$

Table 2.2. Site Condition Attributes

Attribute	**Maximum Score**
Recruitment of woody perennial species in ecological dominant layer (EDL) (%)	5
Native plant species richness - trees	5
Native plant species richness - shrubs	5
Native plant species richness - grasses	5
Native plant species richness - forbes and other	5
Tree canopy - median height	5
Tree canopy - cover	5
Native shrub cover (%)	5
Native perennial grass cover (%)	5
Organic litter cover (%)	5
Large trees (euc plus non-euc)	15
Coarse woody debris (m/ha)	5
Non-native plant cover (%)	10
Maximum Total Score	**80**

Site Context

Site context attributes (Table 2.3) were measured in ARC GIS software using ground-verified RE mapping culminating from result of various flora surveys completed in 2009, 2010, 2013, 2017, 2018 and 2019 (3D Environmental 2019) and scored against predefined thresholds for a fragmented landscape (Eyre *et al* 2015). The final score was converted to a value out of a maximum of 3 according to:

$$\left(\frac{Measured\ context\ score}{Maximum\ context\ score\ (20)}\right)x3$$

Table 2.3. Site Context Attributes

Attribute	Maximum Score
Size of patch	10
Context	5
Connectivity	5
Maximum Total Score	**20**

Species Habitat Index

The ability of the site to support a species is scored according to the attributes in Table 2.4 and converted to a value out of 4 by the following.

$$\left(\frac{Measured\ species\ index\ score}{Maximum\ species\ index\ score\ (100)}\right)x4$$

Table 2.4. Species Habitat Index Attributes

Attribute	Maximum Score
Quality and availability of food and habitat required for foraging	25
Quality and availability of habitat required for sheltering and breeding	25
Quality and availability of habitat required for mobility	25
Absence of threats	25
Maximum Total Score	**100**

For each of the habitat attributes, measurable biotic or abiotic indicator(s) reflecting the species requirements were identified by literature review (e.g., hollow abundance). Were an indicator could not be directly measured, a surrogate measure was selected. Future offset assessments may be undertaken by other parties and, as such, indicators already sampled as part of the *BioCondition Assessment Methodology* were used in preference. While, at times, there may have been a better indicator the use of *BioCondition* data ensures the methodology is repeatable and comparable. However for a small number of species a new indicator was required as the *BioCondition* data was insufficient for sampling important habitat features. Selected indicators for fauna species are documented and justified in Sections 3.2.1 to 3.2.10.

2.4 Survey and Project Limitations

The following limitations of this work are noted:

- Habitat attribute scoring developed for this project is purposed only for comparing suitable habitat (i.e., 'core habitat possible' or 'core habitat known'). It does not consider lower value habitat and the HQS does not accurately reflect the possibility of a species occurring as other factors may affect their presence or absence (e.g., historical use, ancient stochastic events etc).
- Where possible the species habitat index is based on indicators selected from the *BioCondition Assessment Methodology*. These may not always be the best indicator of habitat amenity but ensures future surveys use a consistent, comparable and repeatable measure.
- *Absence of Threats* score has been determined for the broad SGP area, as required under the *Guide to determining terrestrial habitat quality v1.3* (DES 2020). This however may not reflect the extent or severity of threats at a property or local area scale.
- Site Context, Site Condition and Species Habitat Index has been calculated for each BioCondition site and represents a Habitat Quality Score (HQS) for the sampled vegetation polygon. While noting there are some restrictions in land access, effort has been made to encompass spatial and temporal (seasonal) variation in the selection of appropriate HQS sites to achieve a representative sample of habitat variation throughout the SGP areA. Sites were also selected to cover as many different Ecological Stratifications Units (ESUs) as are available in the SGP area, including remnant, regrowth and disturbed REs.
- Habitat amenity has been assessed for REs known within the SGP including 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.14, 11.3.17, 11.3.18, 11.3.25, 11.3.26, 11.3.27, 11.4.3, 11.5.1, 11.5.4, 11.5.20, 11.5.21, 11.7.2, 11.7.4, 11.7.5, 11.7.6, 11.7.7, 11.9.2, 11.9.7 and 11.9.10. A separate assessment for suitability will be required for other REs present within offset properties but not within the SGP. As such the list of suitable REs provided for each MNES value in this document should not be considered exhaustive.

3.0 Assessment Results – Habitat Quality Scores

Habitat quality scores were calculated for sites within REs considered to be suitable habitat for each target MNES value. Individual scores and measured values for each site are provided within the supporting data package[1] with a summary of results provided in the below sections.

3.1 Threatened Ecological Communities

3.1.1 Brigalow communities (*Acacia harpophylla* dominant and co-dominant)

Habitat quality scores for sites within Brigalow communities of the SGP are provided in Table 3.1 below.

Table 3.1. Habitat Quality Scores for assessed Brigalow sites

Regional Ecosystem	Site	Site Condition	Site Context
11.3.1	CS2	1.46	1.35
	CN10	2.44	0.90
	RR10	2.12	0.30
	RR11	1.91	0.30
	RR12	1.99	0.00
	AE06	1.67	1.35
11.4.3	S6	2.06	0.60
	AE01	2.42	2.10
	AE45	2.16	0.90
	AE74	1.54	0.30
Brigalow Regrowth (11.3.1)	CN8	1.44	0.30
Brigalow Regrowth (11.4.3)	CN14	2.14	0.00

3.1.2 Coolibah-Black Box woodlands of the Darling Riverine Plains and the Brigalow Belt South (BBS) bioregion

Habitat quality scores for sites within Coolibah-Black Box communities of the SGP are provided in Table 3.2 below.

Table 3.2. Habitat Quality Scores for assessed Coolibah-Black Box woodland sites

Regional Ecosystem	Site	Site Condition	Site Context
11.3.3	CS19	1.56	2.16
	CS21	1.56	2.16

[1] 'SGP Combined site condition&context scores_Jun 21.xlsx' and 'SGP Combined Threatened Values HQS_Jun 21.xlsx'

3.2 Threatened Fauna Species

3.2.1 Collared Delma (*Delma torquata*)

3.2.1.1 Likely Occurrence

The Collared Delma is a small fossorial legless lizard restricted to the south-eastern area of Queensland. Most records are located in steep hills and slopes around Toowoomba, the Bunya Mountains and areas around the western suburbs of Brisbane. Scatter records occur along the ranges to Kroombit Tops and Don River State Forest west of Gladstone, and they have also been located in ranges associated with Carnarvon Gorge and Expedition National Parks. A cluster of records is present to the west of Roma associated with roadside Poplar Box (*E. populnea*) on alluvial plains (probably RE11.3.2). A single lone record is located approximately 65 km south of the SGP boundary near Wondul Range National Park (probably RE11.9.10).

These records suggest the species is extremely rare and scattered west of the coastal ranges (i.e, Bunya Mountains/Toowoomba Range) and, with the exception of the Roma population, is typically associated with topographically complex areas. Wilmer *et al* (2020) hypothesised *D. torquata* may be adapted to seasonally cool and semi-arid climates and has a dynamic history of expansion and contraction during the Pleistocene; it may have once been more widely spread during glacial periods. Its persistence in the west in more contemporary times is perhaps more likely in areas with complex topographic relief which may provide pockets of stable cool conditions.

Based on the paucity of records surrounding the SGP (excluding those at Bunya Mountains, an area of very different topography and ecology), the species has been previously assessed as unlikely to occur (EcoSmart Ecology 2017). Recent evidence, as detailed above, suggests the SGP is within a region at this species ecological limit and, as such, predicting is occurrence based on habitat preference is likely to be extremely difficult, if not impossible. While there remains a very low possibility that it could persist in isolated localised areas, it is more likely to be absent from extensive areas of seemingly suitable habitat. It is questionable if offsets are worthwhile for such an unlikely and unpredictable species and, if offsets are provided, it is unrealistic to anticipate evidence of occupation.

The above noted, habitats within the SGP which are most suitable would be associated with topographically complex areas. Generally these are absent from the SGP, further evidence the species is unlikely. However small minor jump-ups and low breakaways (typically no more than 1-2 m high) can be associated with RE11.7.2 and 11.7.4, especially in the very north (i.e., Gurulmundi) and south (i.e., steeper relief extending to Wondul Range). An assessment of habitat amenity for the species has been provided for these REs as well as 11.3.2 and 11.9.10 for consistency with REs identified as relevant by DAWE (2021a).

3.2.1.2 Estimating Species Habitat Attributes

Habitat attribute scoring for *D. torquata* is detailed below. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

<u>Quality of Foraging, Shelter and Breeding habitat</u>

The Collared Delma forages, shelters and breeds in similar habitats without distinction between these life-cycle stages. It inhabits eucalypt dominated woodlands and open forest, usually with abundant native grasses. It shelters under logs, bark and other course woody debris, but particularly favours small to mid-sized rocks (Peck 2012). Mats of leaf litter, typically 30-100 mm thick, may also be important (Davidson 1993). They appear to be highly sedentary and occupy a very small area, possibly using the same rock shelter for most of their life (Ryan 2006).

It is suggested within RE11.3.2, 11.7.2, 11.7.4 and 11.9.10 habitat amenity for 'foraging' be based on the extent of exposed, consolidated rock as this is often associated with topographic complexity (i.e., rocky outcrops). The extent of 'rock', as sampled within the *BioCondition Methodology*, will be used noting possible over or under estimation due to i) the lack of distinction between loose small rocks and large consolidated rock slaps and ii) the possibility of missing exposed rock using a transect. Relatively small threshold values have been selected due to the species ability to occur in areas of little rock outcrop.

Table 3.3. Criteria for scoring 'foraging' habitat amenity for Collared Delma

Extent of rock (%)*	<5	5-8	>9-12	>12-16	>16-20	>20
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

'Shelter and breeding' habitat amenity can be estimated using cause woody debris as recorded by the *BioCondition Assessment Methodology*. High scores for 'shelter and breeding' are based on benchmark values for 11.3.2 as this reflects the lowest cause woody debris value for REs within which the species is known to occur in the southern Brigalow Belt.

Table 3.4. Criteria for scoring 'shelter and breeding' habitat amenity for Collared Delma

Cause woody debris (m)*	0-100	>100-150	>150-200	>200-250	>250-300	>300
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

<u>Quality of Habitat required for Mobility</u>

Limited to no data is available on this species mobility or habitat features which may affect its movement potential. However the species is fossorial and individuals are often located under the same rock suggesting their capacity for movement is extremely limited. Populations may be isolated even if surrounded by suitable but un-inhabited habitat. Provision of shelter sites may be the best estimate of movement quality and the scoring system provided in Table 3.4 is adequate.

Absence of Threats

Documented threats to the species include habitat loss and fragmentation, rock removal, in appropriate fire regimes and invasive weeds (DEWHA 2008; Peck 2012). An assessment of these threats across the matter area (i.e., SGP) are provided in Table 3.5.

Table 3.5. An assessment of individual threats for Collared Delma across the broad SGP

Threat	Scope	Severity	Score
Ongoing loss and fragmentation of habitats	Difficult to estimate, but likely < 20% of the SGP affected in next 10 years (score = 5).	No resident Collared Delma populations are known from within the SGP. Within the impacted areas 100% of habitat will be lost, however it is highly unlikely most of these habitats will be, or have ever been, inhabited. While a score of 1 is warranted under a strict interpretation of the criteria (DES 2020), a more realistic score of 5 is warranted as little habitat will be affected.	25
Rock removal	Rock removal within the SGP is highly unlikely to occur and there are no known examples of this impact (score = 5).	The impacts of rock removal in affected areas could theoretically have a moderate impact on habitats or populations. However as argued above (for habitat loss), actual or potential habitat is unlikely and a more moderate score is warranted (score = 5).	25
Inappropriate fire regimes.	Difficult to estimate future fire frequency and extent. Based on historic trends (since 2020), likely to affect 20-39% of the SGP (score = 4).	Within fire affected areas it is likely that a high percentage of habitat will be affected, however as argued above this should be moderated to consider the low probability of the species occurring in affected areas (score = 5).	20
Invasive weeds	While weeds have the potential to affect large areas of vegetation, REs 11.7.2, 11.7.4 and 11.9.10 are robust and currently have little or no evidence of weed infestation. It is unlikely weeds will significantly increase in these areas. In contrast RE11.3.2 is more susceptible to weeds. RE11.3.2 represents approximately < 20% of the of these four habitats within the SGP (Score = 5).	Within RE11.3.2, weeds have the potential to moderately affect Collared Delma habitats, though the species can occur in modified habitats (Peck 2012). As this species is unlikely to occur across large areas of habitat, a more moderate score is warranted (score = 5).	25

3.2.1.3 Habitat Quality Scores

Habitat quality scores for Collared Delma have been evaluated at sites within the REs 11.3.2, 11.7.2 and 11.7.4. These represent all habitats within the SGP[2] considered likely to provide habitat for the species based on current knowledge. However, as discussed in Section 3.2.1.1 the species is unlikely to occur, if at all, and large areas of habitat will be unoccupied. A summary of the score results is provided in Table 3.6 below, with individual site scores provided in Appendix B.

Table 3.6. Summary of Habitat Quality Scores (out of 10) for Collared Delma (*Delma torquata*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.2	14	2.36	6.93	4.34	1.35
11.7.2	4	7.26	8.22	7.79	0.43
11.7.4	8	4.41	8.60	7.30	1.45

3.2.2 Five-clawed Worm-skink (*Anomalopus mackayi*)

3.2.2.1 Likely Occurrence

Within Queensland *A. mackayi* is known from east of the Condamine River, it has never been recorded west of this geographical feature. Furthermore, the species is found on deep cracking clays supporting remnant native grasslands (RE11.3.21) (DAWE 2021b). The SGP is largely situated west of the Condamine River and has no suitable remnant grasslands. Clearing in recent centuries has created some derived (non-remnant) grassland-like communities but, being fossorial in habitat, the Condamine River possess a significant barrier to dispersal. The possibility of colonisation from populations to the east seems improbable.

To summarise, while the SGP is close to, it remains outside this species known distribution and no suitable habitat is present. This species is not expected to occur. With no suitable habitat within the SGP it is not possible to calculate Habitat Quality Scores.

3.2.3 Yakka Skink (*Egernia rugosa*)

3.2.3.1 Likely Occurrence

Records of Yakka Skink are scattered from Mungkan Kandju National Park (NP) on Cape York Peninsula to near St George and Billa Billa in southern QLD. They are coastal around Bundaberg and extend inland to near Charleville. Most records are centred on the Brigalow Belt between St George and Emerald, Chinchilla and Charleville. Few records are located south and east of Chinchilla and the species is regularly absent from seemingly suitable habitat.

The species is typically found in small family aggregations consisting of a single adult pair and their young, though aggregations of up to 21 individuals have been recorded (Peck *et al* 2016). They inhabit a variety of vegetation communities including Brigalow (*Acacia harpophylla*), Mulga (*A. aneura*), Bendee (*A. catenulata*), Lancewood (*A. shirleyi*), Belah (*Casuarina cristata*), Poplar Box (*E. populnea*), Ironbarks and White Cypress Pine (*Callitris glaucophylla*). They

[2] See Section 2.4 for a list of all REs within the SGP

utilise landzones 3, 4, 5, 7, 9 and 10, but typically avoid locations that may be inundated or flooded (DSEWPC 2011).

Habitat modelling followed by field surveys by Johnson *et al* (2017) located only one Yakka Skink colony in the eastern Brigalow Belt South area (Braemar State Forest to the near west of the SGP). Extensive surveys in other suitable habitat on private and public lands, including Barakula State Forest and several State Forests between Dalby and Inglewood (including Braemar, Dunmore, Western Creek, Kumbarilla and Bringalily), failed to locate the species. They concluded that 'there is likely to be a reduced risk of impacts on Yakka Skink habitat within the eastern Brigalow Belt South compared with areas further west'.

The scattered and meagre records (both recent and historical) despite survey effort suggest the SGP is at or near this species climatic limit (Figure 3.1). Its occurrence is likely to be unpredictable based on habitat amenity. Should Yakka Skinks even be present within the SGP, they are likely to be restricted to small, localised areas while absent from extensive, seemingly suitable habitat. It is questionable if offsets are worthwhile for the Yakka Skink until they have been confirmed within disturbance areas. If offset habitats are provided, it is unrealistic to expect habitation by this species.

3.2.3.2 Estimating Species Habitat Attributes

Habitat attribute scoring for the Yakka Skink is detailed below. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Quality of Foraging, Shelter and Breeding habitat

Yakka Skinks are omnivorous feeding on arthropods, small vertebrates, soft plant materials and fruits (Wilson and Knowles 1988; Ehmann 1992). Measuring food abundance, either directly or indirectly, is problematic. Further, reptiles have low metabolic rates and do not have high energetic requirements (Heatwole and Taylor 1987); these lizards are likely to have ample dietary resources in most habitat types as evident by their occasional occurrence in highly disturbed habitats. Assessing habitat amenity based on 'foraging quality' is likely to be arbitrary and possibly misleading.

Where present Yakka Skink colonies inhabit burrow systems under partially buried rocks, logs and tree-stumps. Both used and abandoned rabbit warrens may also be utilised (Peck *et al* 2016). Lizards will persist in cleared or modified habitats where these shelter sites remain intact and will use stick-raked log piles and spoil heaps (Johnson *et al* 2017). Less often they are known to inhabit human structures such as under and around sheds, houses, loading ramps and hold rubble piles.

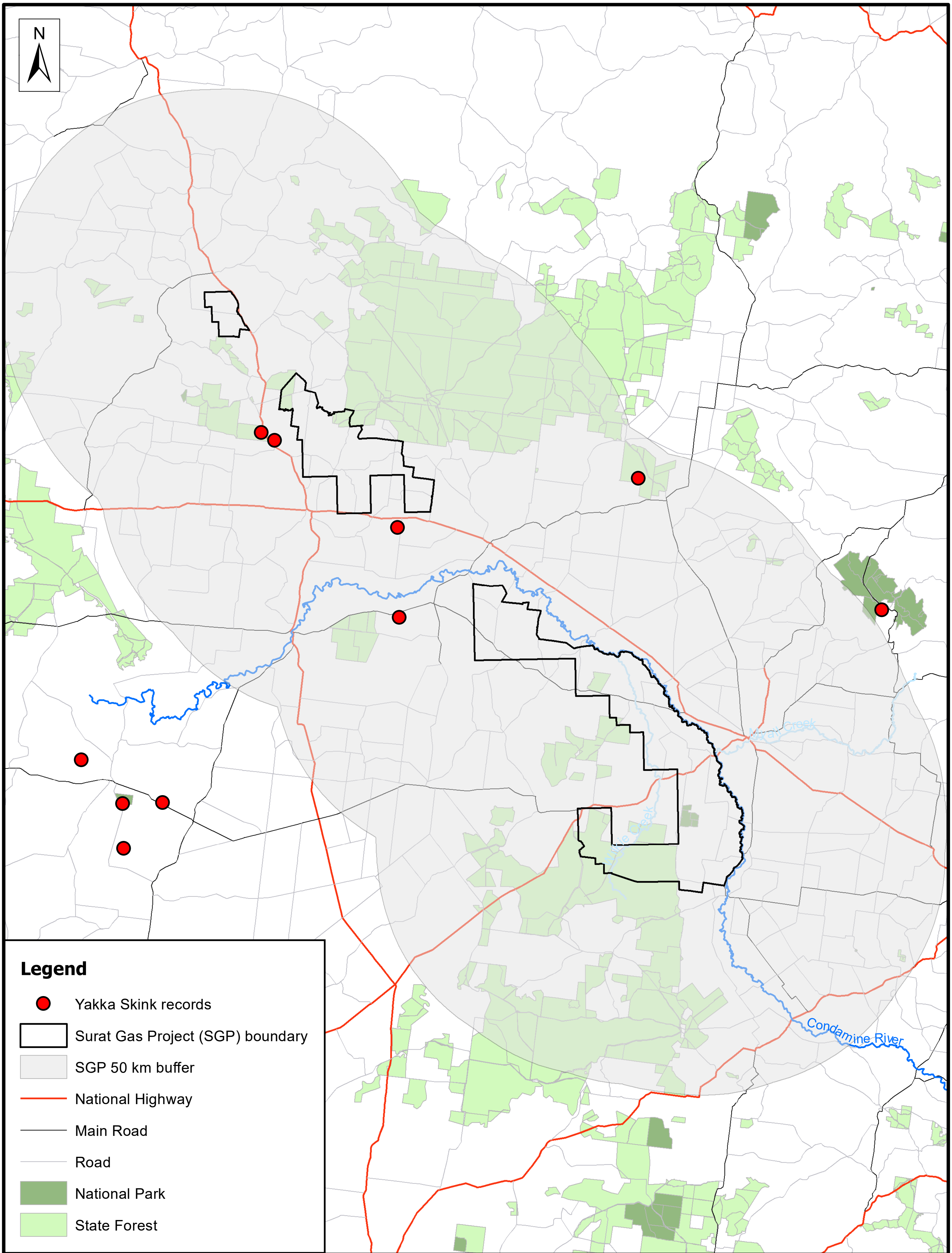

Figure 3.1

Yakka Skink records within 50 km of the SGP project

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

In a research project to identify important habitat features for Yakka Skink in the south-east Brigalow Belt, Johnson *et al* (2017) concluded that these lizards require woodlands and open forests with a soil structure suitable for burrowing (loam and sandy loams, not clay or silt soils), prefer a canopy (T1) height of <16.5 m and woody debris exceeding 37 m^3/ha[3]. However the species could still be present where log volume fell below this threshold if canopy (T1) cover was < 11%.

Based on the above evidence we suggest habitat scoring for Yakka Skink should focus on Canopy (T1) height/cover and log abundance. The influence of soil is considered during habitat suitability mapping which includes REs with suitable soils while avoiding RE's with unsuitable soils. Canopy (T1) height/cover can be used to evaluate 'forage habitat', though it is recognising this is not a score of foraging amenity *per sae* (Table 3.8).

Table 3.7. Criteria and matrix for scoring 'forage' habitat amenity for Yakka Skink

		Median canopy (T1) height (m)				
		<10	10-13	13-16	16-19	>19 m
Canopy (T1) cover*	0-8	25	25	25	20	10
	>8-11	25	20	20	15	5
	>11-15	20	15	15	10	5
	>15-19	15	15	10	5	0
	>19	10	10	10	5	0

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

While log volume would best evaluate 'shelter and breeding' habitat amenity, course woody debris has been selected as this measure is already sampled by the *BioCondition Methodology*. This will ensure a repeatable and consistent measure is used between surveys/assessments. The score should be manually increased if there is evidence of structures that might provide burrows or aid burrow creation (e.g., obvious burrows under rocks, large hollow logs, rabbit warrens).

Table 3.8. Criteria for scoring 'shelter and breeding' habitat amenity for Yakka Skink

Course woody debris (m/ha)^	0-100	>100-200	>200-300	>300-400	>400-500	>500
Score^	0	5	10	15	20	25

^ As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015). Score manually increased if the site contains rabbit burrows (active or abandoned), suitable building debris or rock structures which are considered for Yakka Skink use or burrow creation.

Quality of Habitat required for Mobility

Yakka Skinks show high site fidelity and, while poorly studied, dispersal seems to be limited. At Charleville they were found to disperse between 50 and 570 m (average 260 m; Peck *et al* 2016). Peck *et al* 2016 postulated that dispersal may be unsuccessful if the individual is not able to establish within an existing aggregation. This may explain why the species is often absent from habitats which appear suitable.

[3] Woody debris volume is disproportionately increased by larger logs which provide better habitat for Yakka Skink. This is therefore a better measurement for assessing shelter amenity than total than length.

Habitat factors which affect movement are poorly understood. However it is likely that lizards will be able to move through most habitat types, provided sufficient cover is present to avoid predation. Course ground debris, as measured by using the *BioCondition Methodology*, can be used as a surrogacy to estimate habitat amenity for mobility. However the scoring should be based on total extent of debris and not compared to a benchmark.

Table 3.9. Criteria for scoring 'Mobility' habitat amenity for Yakka Skink

Course woody debris (m/ha)*	< 100	100-200	<200-300	<300-400	<400-500	>500
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

Absence of Threats

Known threats to the species include habitat clearing and fragmentation, introduction of exotic weeds, and modification and the destruction of refugia sites (QPWS 2001; DSEWPC 2011). Suspect threats include (i) degradation of microhabitat features, food supplies and burrow systems from intensive grazing and associated trampling, (ii) inappropriate fire regimes and (iii) predation by feral cats and foxes.

With Yakka Skinks difficult to detect and most suitable habitat not specially protected by legislation, habitat loss for land clearing remains a threat to the species within and around the SGP. Quantifying the extent of this loss is difficult to predict. Predicting the possible impact from weeds, intensive grazing and predation from feral predators is also difficult to predict with some areas likely to be more susceptible than others; however all these impacts are likely to occur across a broad areA. All these impacts will be significantly influenced by land use and likely to vary from location to location, assessing impact on this species is problematic and even determining which threat factor possesses the greatest risk to the species in the SGP is difficult.

Overall, impacts to this species within the next decade is estimated to possibly affect 40-59% (a medium scope) of habitat within the SGP and possibly degrade or reduce the species habitat by 5-10%. This results in an absence of threat score of 12 for the broad SGP area, however it should be noted this will vary significantly between properties and land management practices.

3.2.3.3 Habitat Quality Scores

Habitat quality scores for Yakka Skink have been evaluated at sites within the REs 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.14, 11.3.17, 11.3.18, 11.5.1, 11.5.4, 11.5.20, 11.5.21, 11.7.4, 11.7.5, 11.7.6 and 11.7.7. While these represent most of the suitable REs within the SGP[4], the following REs have not been assessed: 11.9.2, 11.9.7 and 11.9.10 due to land access restrictions A summary of scores for each RE is provided in Table 3.10 with scores for individual sites provided in Appendix B. As discussed in Section 3.2.3.1 the species is unlikely to occur, if at all, and large areas of habitat will be unoccupied.

[4] See Section 2.4 for a list of all REs within the SGP

Table 3.10. Summary of Habitat Quality Scores (out of 10) for Yakka Skink (*Egernia rugosa*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.1	6	2.89	6.22	4.64	1.22
11.3.2	14	2.44	6.81	4.36	1.26
11.3.3	2	3.04	3.44	3.24	0.28
11.3.4	14	2.78	6.20	4.18	1.15
11.3.14	3	3.41	6.21	4.44	1.54
11.3.17	6	3.42	5.82	4.75	0.90
11.3.18	4	2.98	5.35	4.49	1.04
11.5.1	5	4.90	7.71	6.01	1.13
11.5.4	6	3.44	5.17	4.31	0.66
11.5.20	7	2.82	7.60	5.46	1.91
11.5.21	1	5.16	5.16	5.16	n/a
11.7.4	8	3.49	7.64	6.50	1.33
11.7.5	1	6.58	6.58	6.58	n/a
11.7.6	5	5.73	7.21	6.47	0.56
11.7.7	5	4.40	7.45	6.57	1.27

3.2.4 Dunmall's Snake (*Glyphodon dunmalli*)

3.2.4.1 Likely Occurrence

Dunmall's Snake (*Glyphodon dunmalli,* previously *Furina dunmalli*) is confined to the Brigalow Belt bioregion of south-eastern Queensland and north-eastern New South Wales, occurring north to Clermont and near Rockhampton. Most records are from the Dalby-Tara area of the Darling Downs (Hobson 2012). The SGP area is entirely contained within the species distribution. The species is very rarely encountered, even in areas of known habitat, and has been described as 'extremely secretive, rarely encountered, possibly genuinely scarce' (Wilson 2015).

The Dunmall's Snake has been recorded from a number of locations surrounding the SGP including two records approximately 6-7 km to the west. One of these is undated and likely very old while the second is dated as the year 2000. Three records fall within the SGP, two at Lake Broadwater (dated as 1984 and 1993) and a third recent record (post 2015) to the north (-26.425189, 150.182572). These three onsite records have been recorded from RE11.5.1 and regrowth RE11.5.20.

Limited information is available on habitat preferences of the Dunmall's Snake. It has been recorded from a wide range of habitats, including forests and woodlands dominated by brigalow (*Acacia harpophylla*) and other acacias (*A. burowii, A. deanii, A. leiocalyx*), cypress (*Callitris* sp.) or Bulloak (*Allocasuarina luehmannii*) on black alluvial cracking clay and clay loams (Covacevich *et al*. 1988; Stephenson and Schmida 2008; Brigalow Belt Reptiles Workshop 2010; Hobson 2012). It also occurs in spotted gum (*Corymbia citriodora*) and ironbark (*Eucalyptus crebra* and *E. melanophloia*) on sandstone derived soils and there is a record from the edge of dry vine scrub (Stephenson and Schmida 2008; Brigalow Belt Reptiles Workshop 2010). However, preferred habitat appears to be brigalow growing on cracking black clay and clay loams (Cogger *et al.* 1993), with the majority of records from between 200 to 500 m elevation (Hobson 2012). The species can, on rare occasions, inexplicably appear in sub-optimal vegetation. Advanced regrowth habitat should not be discounted, particularly when adjacent or linking areas of suitable habitat.

Modelling completed by Johnson *et al* (2017) failed to find any reliable attributes for predicting suitable habitat for this species. While the model had limited predictive ability, it showed that the Dunmall's Snake was associated with several Broad Vegetation Groups (BVG) within the southern Brigalow Belt (Table 3.11). All RE's listed in the table below have been identified as contributing to 'Core Habitat Possible' (EcoSmart Ecology 2017) except RE11.3.2 and RE11.3.26. These should be elevated from 'General Habitat' to 'Core Habitat Possible' for future assessments and mapping.

Table 3.11. Association of Dunmall's Snake records with 1:1M Broad Vegetation Groups (Modified from Johnson *et al* 2017; only BVGs/REs relevant to the SGP listed)

BVG	Description	RE's assessed within SGP
10a	Dry woodlands to open woodlands dominated by *Corymbia citriodora* (Spotted Gum). (land zones 10, 7, 12, 11).	11.7.6
12a	Dry woodlands to open woodlands dominated by ironbarks such as *Eucalyptus decorticans* (Gum-topped Ironbark), *E. fibrosa* subsp. *nubila* (Blue-leaved Ironbark), or *E. crebra* (Narrow-leaved Red Ironbark) and/or bloodwoods such as *Corymbia trachyphloia* (Yellow Bloodwood), *C. leichhardtii* (Rustyjacket), *C. watsoniana* (Watson's Yellow Bloodwood), *C. lamprophylla, C. peltata* (Yellowjacket). Occasionally *E. thozetiana* (Mountain Yapunyah), *E. cloeziana* (Gympie Messmate) or *E. mediocris* are dominant. Mostly on sub-coastal/inland hills with shallow soils. (land zones 7, 9, 10).	11.7.4, 11.7.7
13d	Woodlands dominated by *Eucalyptus moluccana* (Gum-topped Box or *E. microcarpa,* Inland Grey Box) on a range of substrates. (land zones 3, 5, 8, 9, 11, 12).	11.3.26, 11.5.20
17a	Woodlands dominated by *Eucalyptus populnea* (Poplar Box) (or *E. brownii*, Reid River Box) on alluvium, sand plains and footslopes of hills and ranges. (land zones 3, 4, 5, 9, 10, 11, 12).	11.3.2, 11.3.18, 11.9.7
18b	Woodlands dominated *Eucalyptus crebra* (*sens. lat.*) (Narrow-leaved Red Ironbark) frequently with *Corymbia* spp. or *Callitris* spp. on flat to undulating plains. (land zones 3, 5).	11.5.1, 11.5.4
25a	Open forests to woodlands dominated by *Acacia harpophylla* (Brigalow) sometimes with *Casuarina cristata* (Belah) on heavy clay soils. Includes areas co-dominated with *A. cambagei* (Gidgee) and/or emergent eucalypts. (land zones 3, 4, 7, 9, 11).	11.3.1, 11.3.17, 11.4.3, 11.4.10, 11.9.5, 11.9.10

3.2.4.2 Estimating Species Habitat Attributes

Habitat attribute scoring for the Dunmall's Snake is detailed below. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

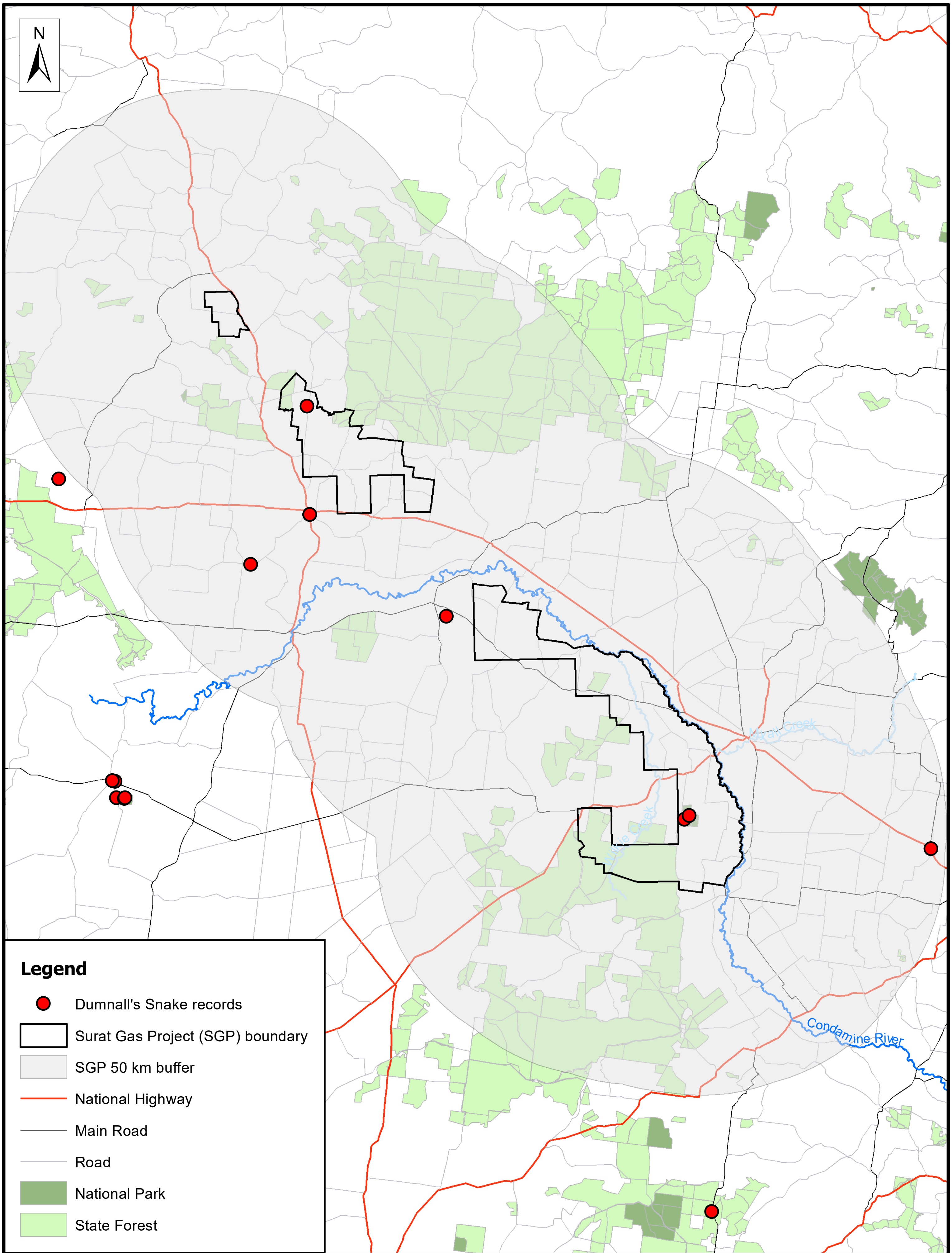

Figure 3.2

Dumnalls Snake records within 50 km of the SGP project

Scale:

1:1,162,653

0 5 10 20 30 40

Kilometers

ecosmart ECOLOGY

Client: Arrow Energy	**Project:** SGP OAMP BioCondition and HQS Report

Quality of Foraging, Shelter and Breeding Habitat

The Dunmall's Snake diet is thought to consist of small terrestrial reptiles with abundant populations potentially providing better foraging habitat. Many of these reptiles shelter under fallen woody debris. In reality snakes have low metabolic rates and low energetic requirements (Heatwole and Taylor 1987) and prey abundance may not influence habitat selection. Further, terrestrial lizard abundance could be affected by other factors such as climatic conditions with anecdotal reports of small terrestrial lizard communities declining after severe long-term drought (M. Sanders *pers. obs.*). However, in the absence of a better measurable attribute, total fallen woody debris (metres/hectare) is probably the best factor to consider.

Where these snakes shelter largely remains a mystery but is presumed beneath fallen debris similar to other snakes. However few have been located when not active; one has been located under a log (S. Wilson *pers. comm.*) while a second approximately two metres off the ground under bark on a large dead tree (M. Summerville *pers. comm.*). The lack of sheltering observations have led some to believe they may be subterranean in habitat, possibly sheltering down deep soil cracks. At least three individuals, possibly the highest number at any one location, have been found at Erringibba National Park which is dominated by deep cracking clays (RE11.4.3/11.4.7). However they have been found at other locations where deep soil cracks are not abundant (including two recent records from Kroombit Tops National Park).

A similar lack of evidence and poor ecological understanding confound evaluating and scoring 'mobility' habitat.

A model based the on habitat at historic locations developed by Johnson et al (2017) was 'not useful for the purpose of identifying areas of potential habitat for the species but does indicate a very broad environmental envelop in which the species may possibly occur'.

To put it simply, there is no good way to assess shelter, breeding or mobility habitat amenity for these snakes. In the absence of any substantial evidence, total fallen woody debris (metres/hectare) will be used as the assessment attribute. How to score or rank the amount of woody debris is largely arbitrary.

Table 3.12. Criteria for scoring 'forage', 'shelter and breeding' and 'mobility' habitat amenity for Dunmall's Snake

Course woody debris (meters per hectare)*	< 100	100-200	<200-300	<300-400	<400-500	>500
Score*	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology. Score for 'shelter and breeding' and 'mobility' amenity to be manually adjusted (increased) as required to account for addition shelter provided by soil cracks.

Absence of Threats

Possible threats have been identified as (DAWE 2021c):

- Extensive clearing of habitat for development (mining and urban), agriculture or pasture improvement
- Extensive overgrazing of habitat by domestic stock
- Loss of fallen timber and ground litter, e.g. fuel reduction burns, firewood collection

- Invasion of habitat by predatory animals and introduced weeds
- Possible drainage of swamps.

As Dunmall's Snakes are extremely difficult to detect and much of their potential habitat is not specially protected by legislation, habitat loss remains a threat to the species within and around the SGP. Quantifying the extent of this loss is difficult to predict. Predicting the possible impact from weeds, intensive grazing and predation from feral predators is also difficult to predict with some areas likely to be more susceptible than others; however all these impacts are likely to occur across a broad areA. As all these impacts will be significantly influenced by land use and likely to vary from location to location, assessing impact on this species is problematic and even determining which threat factor possesses the greatest risk to be species in the SGP is difficult. Furthermore, it is almost impossible to assess how much suitable habitat might be frequented by the species within the SGP.

Impacts to this species within the next decade is estimated to possibly affect 40-59% (a medium scope) of habitat within the SGP and possibly degrade or reduce the species habitat by 5-10%. This results in an absence of threat score of 12 for the matter (SGP) area. It should be noted this will vary significantly between properties and land management practices, and due to the uncertainty around this species ecology there is low confidence of this estimate.

3.2.4.3 Habitat Quality Scores

Habitat quality scores for Dunmall's Snake have been evaluated at sites representing all suitable REs within the SGP except RE11.9.7 and 11.9.10. A summary of scores for each RE is provided in Table 3.13 with scores for individual sites provided in Appendix B.

Table 3.13. Summary of Habitat Quality Scores (out of 10) for Dunmall's Snake (*Glyphodon dumnalli*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.1	6	2.69	6.82	4.91	1.59
11.3.2	14	2.04	7.01	4.25	1.57
11.3.14	3	3.61	7.01	4.77	1.93
11.3.17	6	2.62	6.42	4.95	1.52
11.3.18	4	2.58	5.15	4.14	1.10
11.4.3	1	5.34	5.34	5.34	n/a
11.5.1	5	4.10	8.11	6.09	1.69
11.5.4	6	3.29	4.91	4.11	0.70
11.5.20	7	2.75	8.60	5.91	2.34
11.5.21	1	4.96	4.96	4.96	n/a
11.7.2	4	6.14	8.30	7.42	0.91
11.7.4	8	3.69	8.24	6.58	1.47
11.7.6	5	6.33	8.21	6.99	0.75
11.7.7	5	4.40	7.96	7.01	1.53

3.2.5 Squatter Pigeon (Geophaps scripta scripta)

3.2.5.1 Likely Occurrence

The SGP occurs entirely within the distribution of the Squatter Pigeon. However Squatter Pigeons have been recorded on only six occasions within, or in proximity to (<20 km), the SGP and off-tenure areas since 2010. On average the species is recorded less than once a year, despite being a relatively easy species to observe. There are no repeat records from the same location or general area, not even Lake Broadwater which represents perhaps be the best Squatter Pigeon habitat within the eastern Condamine Catchment. As such Squatter Pigeons recorded from the SGP and surrounding area are suspected transient individuals and no resident or breeding populations are known to occur.

Based on the lack of frequent or repeated representation within or near Arrow tenements, or any evidence of resident/seasonal populations within the region, early assessments considered Squatter Pigeons to be a 'transient' species and no detailed habitat mapping has been undertaken. To comply with DoEE requirements new rules were developed in 2019 to allow predictive mapping of potential habitats. It should be noted mapped habitats within the SGP are unlikely to represent areas inhabited by a population that is important for the species' survival, though they may be of some value if the species was to undergo sudden expansion.

Considering the species is rarely recorded within the SGP and no known populations occur, it is unrealistic to expect evidence of this species in offset vegetation.

3.2.5.2 Estimating Species Habitat Attributes

Habitat attribute scoring for the Squatter Pigeon is detailed below. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Foraging, Shelter and Breeding, and Mobility Habitat

Squatter Pigeons spend most of their life-cycle in similar habitats for foraging, sheltering, breeding, and movement. They occur in open-forests to sparse open woodlands that are dominated by Eucalyptus and in close proximity (typically < 3 km) to permanent or semi-permanent water. This includes remnant and non-remnant habitats such as grazing lands. Sandy or gravel soils which have a sparse to patchy ground layer that rarely exceeds 33% are particularly favoured (DAWE 2021d). Individual birds may be sporadically observed in atypical habitats such as more heavily wooded vegetation, where they are usually observed along roadsides, tracks and other areas where there is a break in the canopy.

Nests are positioned on the ground with eggs laid in a slight depression lined with grasses and sheltered by tussock grass, shrubs, or debris (Frith 1982; Beruldsen 2003). They are likely to be capable of breeding in any month following suitable conditions, but their main breeding season is September to January (Cooper et al 2014).

Squatter Pigeons are not known to undertaken long-distance movements (1982), though there is evidence to suggest dispersal may be more widespread than currently recognised (Cooper *et al* 2014). They are highly mobile birds able to cover large distances quickly over a variety of remnant and non-remnant habitats.

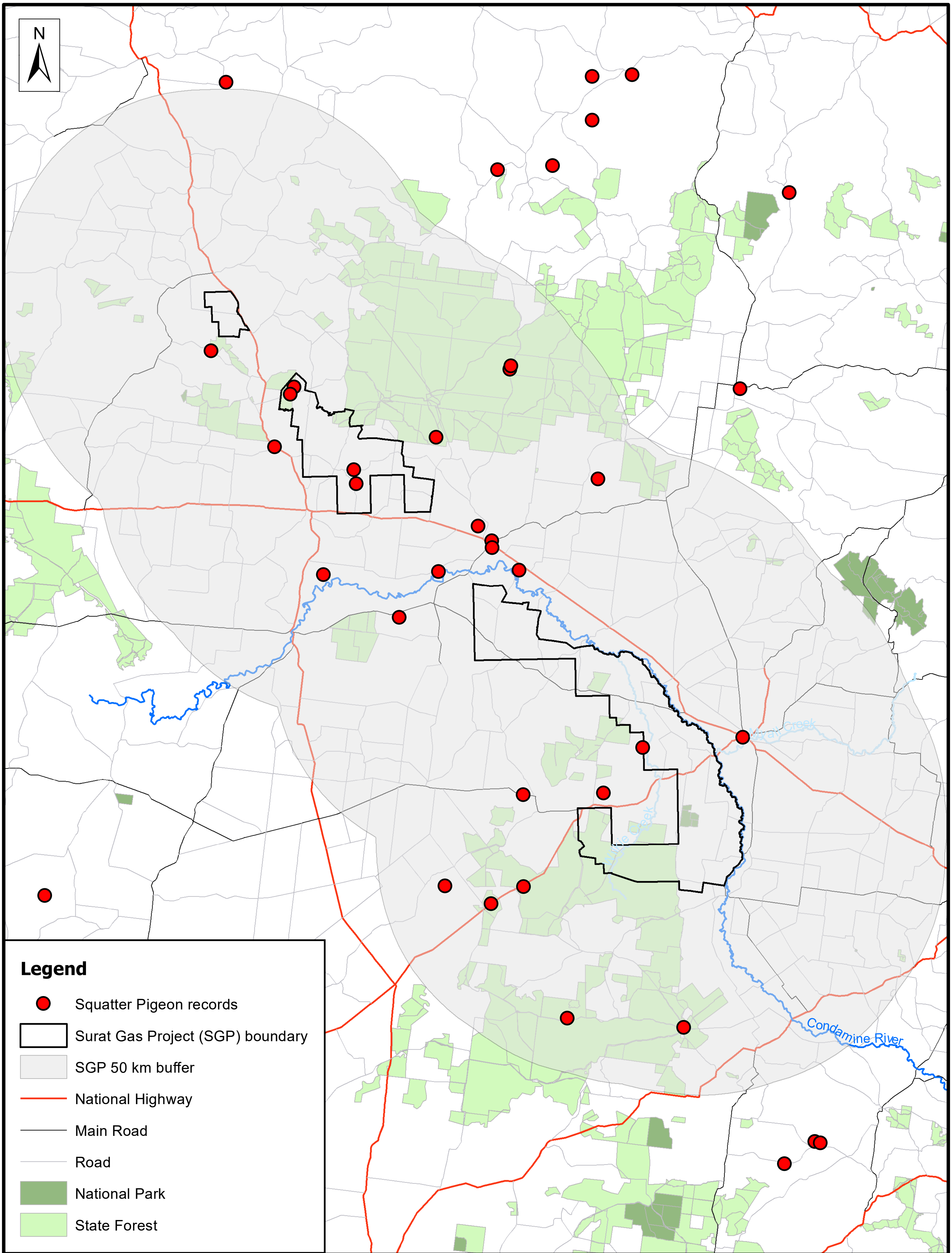

Figure 3.3

Squatter Pigeon records within 50 km of the SGP project

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

Based on known habitat use three factors seem best to predict habitat amenity for this species: percentage canopy cover, ground cover, and distance to water. Canopy cover can be used for scoring 'shelter and breeding' habitat, ground cover for 'forage' habitat and distance to water for 'mobility' habitat.

Table 3.14. Criteria for scoring 'forage' habitat amenity for the Squatter Pigeon

Leaf/debris + bare ground (%)*	< 60	≥60-70	≥70
Score	0	15	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

Table 3.15. Criteria for scoring 'shelter and breeding' habitat amenity for the Squatter Pigeon

% canopy (T1+T2) cover*	0-30	>30-50	>50-60	>60-70	>70-80	>80
Score	25	20	15	10	5	0

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

Squatter Pigeons are able to use a variety of water resources, including minor features such as water troughs (M. Sanders *pers. obs*). These features are difficult to detect using aerial photography and as such the mobility score may not always accurately reflect on-ground conditions. Manual variation of these scores may be included if justified based on ground-verified results.

Table 3.16. Criteria for scoring 'mobility' habitat amenity for the Squatter Pigeon

Distance to water (km)	0-1	>1-2	>2-3	>3-4	>4-8	>8
Score	25	20	15	10	5	0

Absence of Threats

Documented threats to the Squatter Pigeon include (DAWE 2021d):

- Loss and fragmentation of habitats
- Degradation of habitat by domesticated herbivores (e.g., sheep and cattle)
- Degradation of habitats by exotic weeds (e.g., Buffel Grass *Cenchrus ciliaris*)
- Predation from native and exotic (especially fox and cat) predators

An assessment of each threat across the SGP areas is provided in Table 3.17 below. The scope and severity of these impacts are difficult to evaluate without empirical data.

Table 3.17. An assessment of individual threats for Squatter Pigeon across the broad SGP

Threat	Scope	Severity	Score
Ongoing loss and fragmentation of habitats	Difficult to estimate, but likely < 20% of the SGP affected in next 10 years (score = 5).	No resident Squatter Pigeon populations are known from within the SGP. It is unlikely potentially cleared areas will be recolonised within the next decade, and as such less than 5% of known habitat likely affected (score = 5).	25
Increased degradation by	Most areas of retained habitat are contained within reserves	The level of damage from this threat is difficult to estimate and is likely to vary	8

Threat	Scope	Severity	Score
domesticated herbivores	(State Forest) or along waterways. Most of these areas will experience at least some grazing pressure in the next decade, likely more than 60% (score = 2).	between properties and management units. While grazing pressures may prevent habitat recovery, it is unlikely to lead to a significant increase in habitat degradation (score = 4).	
Degradation of habitats by exotic weeds	All areas of retained Squatter Pigeon habitat could be affected, in varying degrees, by exotic weeds within the next decade (score = 1).	Difficult to assess across the broader SGP with some areas more susceptible than others. Large areas of habitat already infested by weeds preventing habitat recovery, however future weed infestations unlikely to significantly reduce existing habitats in next 10 years (score = 5).	5
Predation from native and exotic predators	All areas of retained Squatter Pigeon habitat is, and could be, affected by predation within the next decade (score = 1).	Difficult to estimate across the broader SGP due to location-specific variation. Considering there is no existing population it seems unlikely this threat will significantly reduce the population future. It may however reduce the success of recovery (score = 5).	5

3.2.5.3 Habitat Quality Scores

Habitat quality scores for Squatter Pigeon have been evaluated at sites representing all suitable REs within the SGP except RE11.3.26, 11.9.2 and 11.9.7. A summary of scores for each RE is provided in Table 3.18 with scores for individual sites provided in Appendix B.

Table 3.18. Summary of Habitat Quality Scores (out of 10) for the Squatter Pigeon (*Geophaps scripta scripta*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.2	14	2.11	4.63	3.41	0.80
11.3.3	2	2.66	2.86	2.76	0.14
11.3.4	14	2.85	4.92	3.58	0.67
11.3.14	3	1.83	4.18	3.23	1.23
11.3.17	6	2.69	4.19	3.40	0.60
11.3.18	4	2.57	4.84	3.67	1.18
11.3.25	6	3.55	5.18	4.49	0.61
11.3.27f	1	2.65	2.65	2.65	n/a
11.3.27i	4	3.14	4.46	3.72	0.55
11.5.20	7	2.66	5.91	4.42	1.48

3.2.6 Painted Honeyeater (*Grantiella picta*)

3.2.6.1 Likely Occurrence

The SGP area occurs entirely within the distribution of the Painted Honeyeater and the species has been frequently recorded within a 20 km buffer. With the exception of a single location identified in 2019, records within the SGP are restricted to the immediate vicinity of Lake Broadwater (Figure 3.4).

Painted Honeyeaters inhabit open dry woodlands and forests which have abundant Mistletoe (Higgins *et al* 2001). They prefer extensive stands of remnant woodlands with mature trees as these support more mistletoe, but will use narrow strips and small blocks if sufficient mistletoe fruit is available (DAWE 2020).

Within the southern Brigalow belt vegetation which supports abundant Needle-leaved (*Amyema cambagei*) and Grey Mistletoe (*A. quandang*) are particularly favoured. Needle-leaved Mistletoe is associated with *Casuarina cunninghamiana* and *Casuarina cristata,* while Grey Mistletoe is associated with larger *Acacia* species (especially *A. harpophylla*). Riparian woodlands (e.g., *E. camaldulensis* waterways) can also be utilised if mistletoe is abundant.

3.2.6.2 Estimating Species Habitat Attributes

Habitat attribute scoring for Painted Honeyeater is detailed below. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Foraging, Shelter and Breeding Habitat

Painted Honeyeaters are mistletoe specialists and their diet is dominated by mistletoe fruit and, at certain times of the year, mistletoe nectar (Oliver *et al* 2003). Invertebrates can also be occasionally taken (Higgins *et al* 2001). Nests are located in the outer foliage of trees, especially eucalypts and casuarinas, and mistletoes which have pendulous foliage (Higgins *et al* 2001; Barea 2008). Studies have found that nest-site selection is primarily driven by mistletoe abundance and proximity to mistletoe clumps, although habitat structure also plays a role (Barea 2012).

Based on a study in northern NSW, Painted Honeyeaters inhabit sites where mistletoe density averages 260 mistletoe clumps per hectare, though mistletoe density may range from five to 1,505 clumps per hectare (Oliver *et al* 2003). Home range size is poorly documented, however nesting pairs can often be found in linear fragments and small patches of vegetation that are likely less than one hectare (M. Sanders *pers. obs.*).

As the life-cycle of the Painted Honeyeater is primarily driven by mistletoe phenology (Barea and Watson 2007), scoring foraging habitat and breeding habitat amenity should both reflect mistletoe density. No existing *BioCondition Methodology* attribute measures mistletoe abundance and, as such, all future offset surveys must measure mistletoe density as a new attribute. While the species is most often associated with *A. cambagei* and *A. quandang* in the southern Brigalow Belt, it remains unclear if this is a preference for these two species or reflects that these two species of mistletoe can often be found in high density populations. A precautionary approach is applied and all mistletoe is considered of equal value in the scoring below.

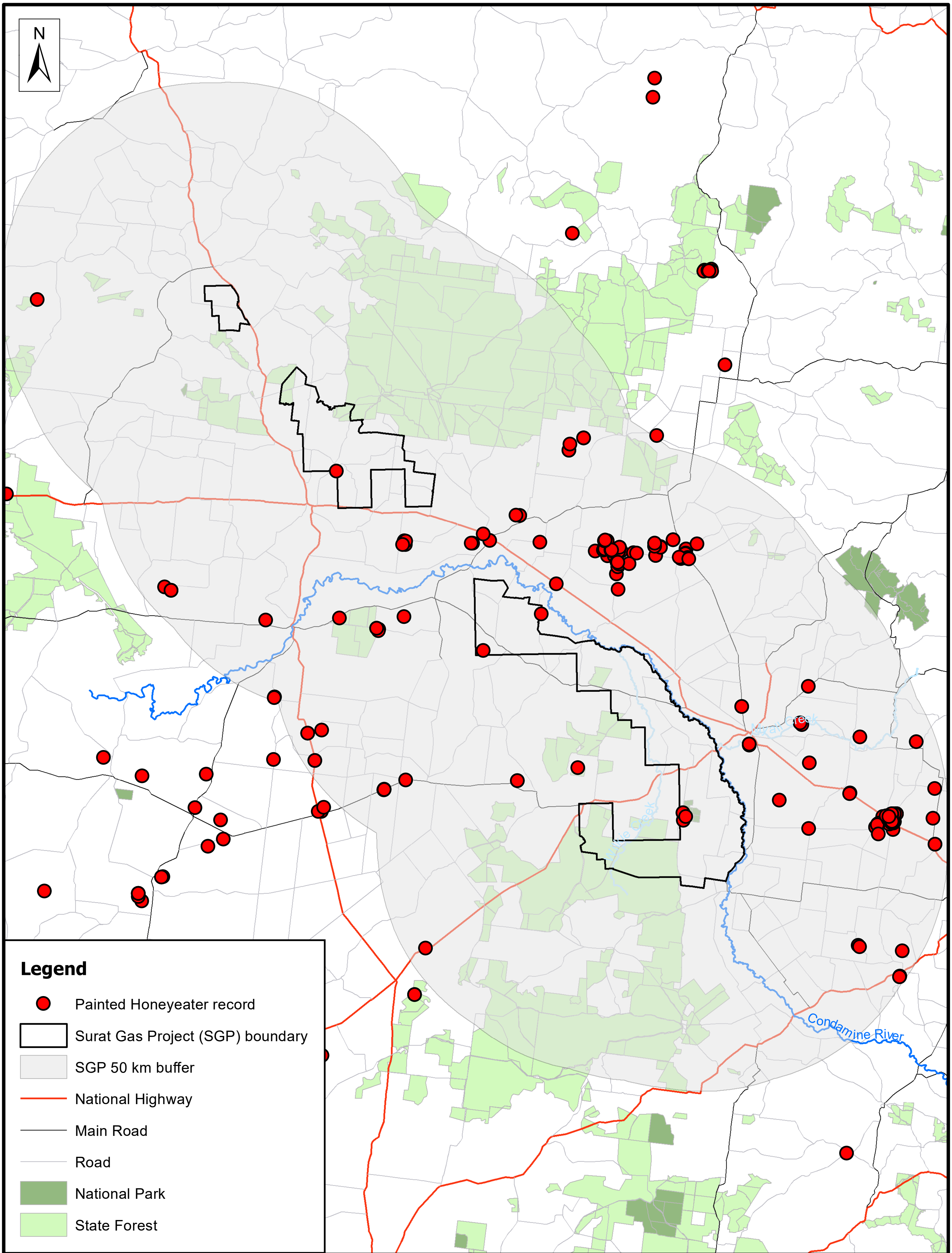

Figure 3.4

Painted Honeyeater records within 50 km of the SGP

Scale:

1:1,159,411

0 5 10 20 30 40
Kilometers

ecosmart ECOLOGY

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

Table 3.19. Criteria for scoring 'forage' and 'shelter and breeding' habitat for Painted Honeyeater

T1 & T2 mistletoe density (No./ha)	0-50	51-100	101-150	151-200	201-250	251+
Score	0	5	10	15	20	25

Quality of Habitat required for Mobility

Painted Honeyeater movements are not well understood though they are generally thought to have a north-south migration pattern. Non-breeding birds move north, typically to areas above 26°S, while spring-summer breeding typically occurs in habitats south of 26°S. At some locations they are considered seasonal visitors while in other areas they are described as irregular or nomadic (Higgins *et al* 2001).

Little information is available on habitat qualities which facilitate movement. However, these birds are highly mobile, can quickly move large distances, and often appear in relatively isolated patches. At some locations they can be irruptive in response to abundant mistletoe fruiting (Oliver *et al* 2003).

It is unlikely any particular habitat, except perhaps very large areas of cultivation or urbanisation, hinder the movement of Painted Honeyeaters. Rather, they are likely easily transit through all remnant habitat types. As such the mobility score for all remnant RE's should be fixed to 25.

Absence of Threats

Current threats to the Painted Honeyeater include (DAWE 2020):

- Habitat loss
- Habitat degradation
- Competition for resources with larger and/or more aggressive honeyeaters
- Climate variability and change increasing the risk of drought, fire and altered flowering or fruiting phenology.

Other threats include predation from invasive species, deliberate destruction of mistletoe in production forests, exacerbation of tree decline for pasture improvement, vehicle collision, and nest predation.

Within the SGP and surrounds Painted Honeyeater habitats are generally associated with abundant *C. cunninghamiana, C. cristata* and *A. harpophylla.* These vegetation types are considered as Endangered in Queensland and protected by legislation ensuring ongoing habitat loss is avoided, at least theoretically. The remaining patches are small in extent, often restricted to roadside reserves. This reduces the risk of wide-spread fire affecting large areas of habitat within a short time-frame but likely increases predation and competition with aggressive honeyeaters (Andrén 1992, Bayne and Hobson 1997, Ford 2011). Their small extent also makes them more susceptible to habitat degradation, particularly on private lands were grazing pressures remain. Increased drought duration and severity may also lead to tree and mistletoe loss, especially in trees already stressed by mistletoe infestations. It is therefore extremely difficult to assess the 'scope' and 'severity' of habitat degradation across the entire SGP with its varied landscape and climatic conditions. Habitats in the west may be more susceptible and more likely to be affected by drought than those in the east, while habitats on private land more likely exposed to grazing and other agricultural pressures.

Generally, these impacts are not likely to not significantly increase over the coming ten years and the severity is therefore estimated as 'Low' (reducing the population by 6-10%). This is slightly less than historic trends which suggest the entire Painted Honeyeater population has declined by 20-29% over 17 years (DAWE 2020). For the purpose of this assessment the 'scope' has been estimated as 'High' (affecting 60-79% of the habitat/population within the matter area). Absence of threats is therefore evaluated as 8.

Due to the complex and interacting threats to remaining Painted Honeyeater habitat, this assessment may require further consideration on a property bases as required.

3.2.6.3 Habitat Quality Scores

Habitat quality scores for Painted Honeyeater have been evaluated at sites representing suitable REs within the SGP except RE11.9.5 and areas of RE11.3.27/11.5.20 around the immediate vicinity of Lake Broadwater. A summary of scores for each RE is provided in Table 3.20 with scores for individual sites provided in Appendix B.

Table 3.20. Summary of Habitat Quality Scores (out of 10) for Painted Honeyeater (*Grantiella picta*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.1	6	3.31	4.66	3.95	0.51
11.3.17	6	3.46	4.86	4.09	0.60
11.4.3	1	4.38	4.38	4.38	n/a
Brig R (11.3.17)	4	2.93	3.27	3.06	0.15
Brig R (11.4.3)	1	5.06	5.06	5.06	n/a

3.2.7 Regent Honeyeater (*Anthochaera phrygia*)

3.2.7.1 Likely Occurrence

The Regent Honeyeater once occurred from Adelaide through south-eastern Australia into south-eastern QLD to about 100 km north of Brisbane. It is a seasonal visitor to the state, typically only present during the winter periods. Most historical records in Queensland are roughly east of Gore, Toowoomba and Maroochydore. Within Queensland it was historically known to breed near Warwick in the Gore-Karara region but is now very sporadically observed (National Environmental Science Program Threatened Species Research Hub 2019).

The species is extremely rare around Dalby with just two records from 2000 and 2002. Both were observed along Myall Creek in or near the town of Dalby, associated with flowering *E. tereticornis*. Several large Mugga Ironbark (*E. sideroxylon*) planted in nearby parks (M. Sanders *pers. obs.*) may have also provided foraging resources at the time. Further west there is an undated (likely decades old) and highly inaccurate (10,000 m) record from Chinchilla and some from the Bunya Mountains.

Available distribution modelling indicates the vast majority of the SGP is outside the species range with only the southern portion falling within an area of low predicted probability (Figure

3.5 and Figure 3.6). 'Maxent' modelling (Stojanovic *et al* in press) based on contemporary records (2000-2010) during the breeding season (July-January) found habitat suitability is influenced by annual rainfall. On balance the SGP falls outside the species main breeding range, though there is low potential in the south-east during extremely wet years (Ross Crates *pers. comm.*)[5].

Based on this evidence the species is highly unlikely to occur within the SGP and habitats within the SGP are unlikely to be critical for the species recovery. Offset requirements therefore seem unnecessarily and, if required, it would be unrealistic to require evidence of offset use by Regent Honeyeaters.

3.2.7.2 Estimating Species Habitat Attributes

This section outlines and justifies scoring attributes for Regent Honeyeater habitat amenity. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Foraging, Shelter and Breeding Habitat

The Regent Honeyeater inhabits woodland and open forests, especially box-ironbark woodland, but also riparian vegetation and lowland coastal woodland. It times it can be found in non-remnant vegetation, trees in farmland, roadside reserves and planted parks and gardens in semi-urban locations. They spent most of their time in the canopy where they feed on nectar and lerps, sometimes taking insects. Taller and larger trees, particularly when on fertile soils, are favoured for foraging as these typically produce more nectar (Menkhorst *et al* 1999; Oliver 2000; DoE 2016).

While there is regional and seasonal variation, several tree and mistletoe species are recognised as important for the Regent Honeyeater (DoE 2016): Mugga (Red) Ironbark (*E. sideroxylon*), Yellow Box (*E. melliodora*), White Box (*E. albens*), Yellow Gum (*E. leucoxylon*), Spotted Gum (*E. maculata*), Swamp Mahogany (*E. robusta*), Needle-leaved Mistletoe (*Amyema cambagei*) on River Sheoak (*C. cunninghamiana*), Box Misteltoe (*A. miquelii*) and Long-flower Mistletoe (*A. vitellina*). With the exception of *A. cambagei*, none of these species occur within the SGP.

Many records of Regent Honeyeater in south-east Queensland, including records at Dalby, are associated with riparian stands or large *E. camaldulensis* and *E. tereticornis* (especially the later). Similar RE's within the SGP are entire restricted to RE11.3.25 and 11.3.27 (sub-types d, f, and i only). Vegetation with abundant River Oak, which might support *A. cambagei*, are also restricted to RE11.3.25.

[5] Noting the SGP area and surrounds is traditionally under-surveyed/birded relative to other parts of the species potential range.

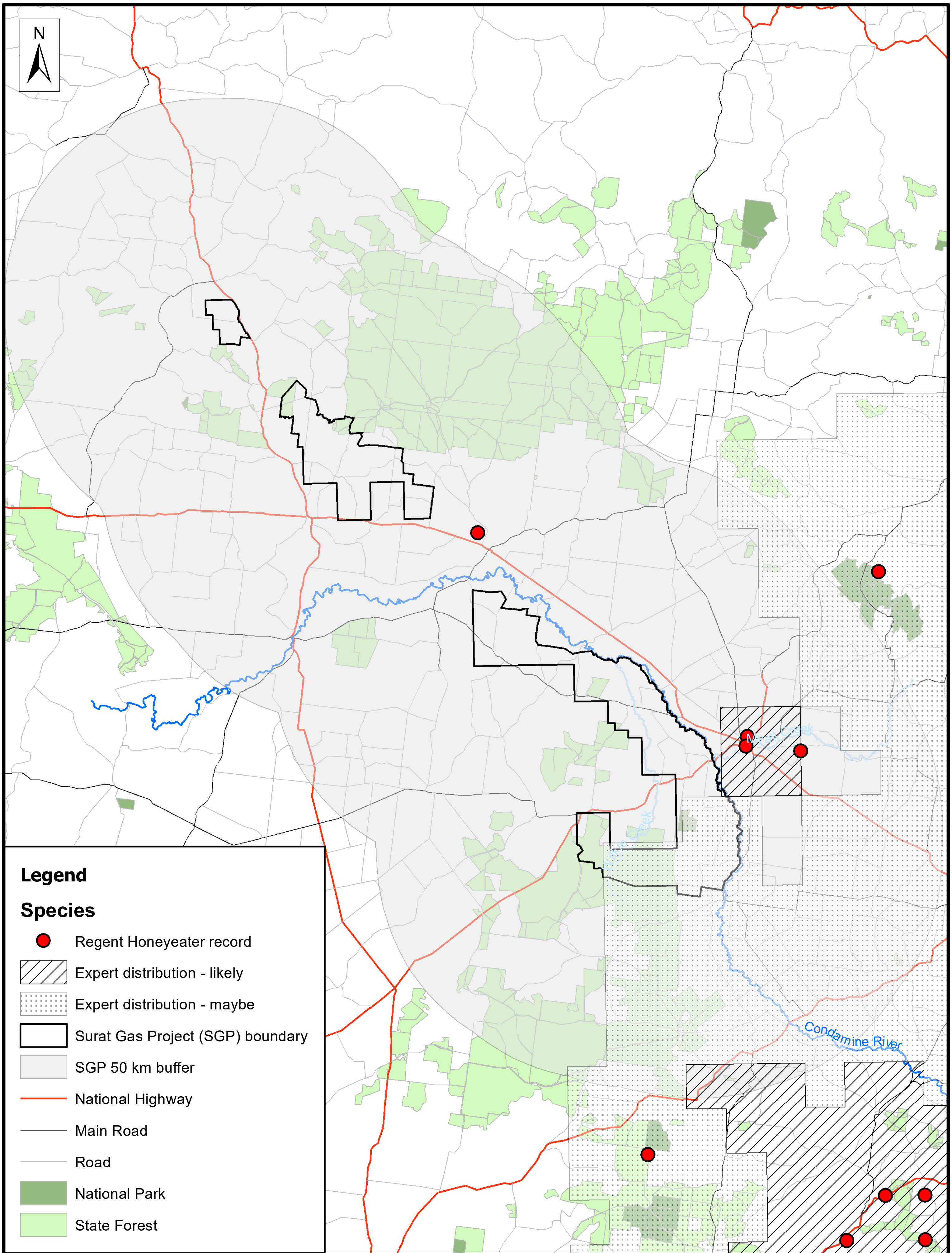

Figure 3.5

Regent Honeyeater records and predictive mapping (ALA) for the SGP and surrounds

Scale:

1:1,170,159

0 5 10 20 30 40

Kilometers

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

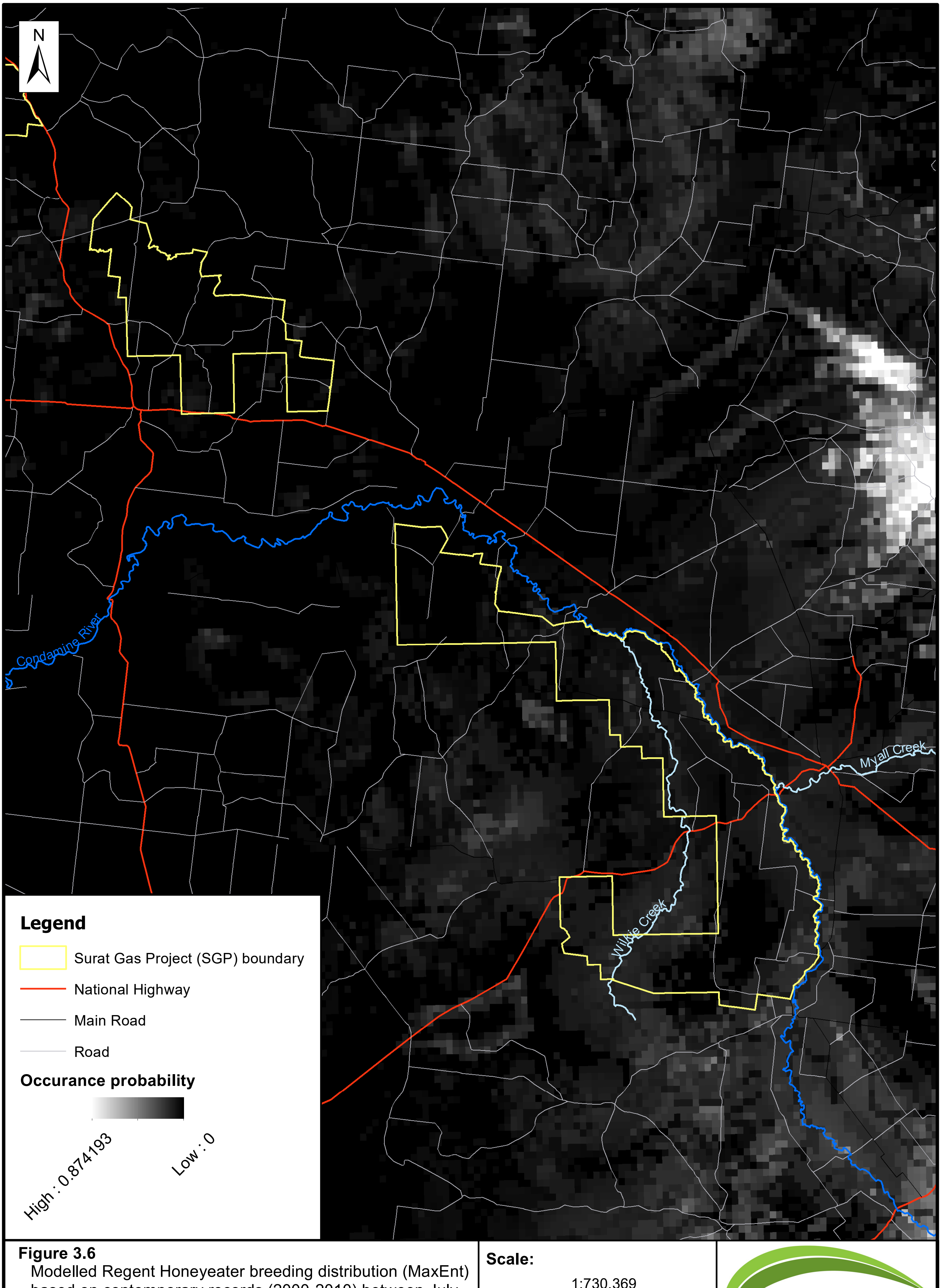

Figure 3.6
Modelled Regent Honeyeater breeding distribution (MaxEnt) based on contemporary records (2000-2010) between July and January.

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

The Regent Honeyeater shelters and breeds in areas of high foraging amenity, no special habitat features distinguish 'foraging' from 'shelter and breeding' habitat. A similar score for both attributes can be achieved by converting the measured 'Number of large trees' (as per the *BioCondition Methodology*) into a score out of 25:

$$\left(\frac{Measured\ BioCondition\ 'No.\ large\ trees'\ score}{Maximum\ 'No.large\ trees'score\ (15)}\right) x\ 25$$

The SGP has is not within the known breeding range of this species and habitats, if present, should be restricted to the above two RE's within the species modelled 'maybe' distribution (i.e., only the south-eastern portion of the SGP area; Figure 3.5).

Mobility Habitat

Regent Honeyeaters undertake regular movements, but their timing and pattern varies between years with seasonal shifts relating to regional flowering phenology (Menkhorst 1997). In south-east Queensland birds are present predominantly in the cooler winter months to coincide with flowering *E. tereticornis* and *E. sideroxylon*. How Regent Honeyeaters use the landscape for movement/dispersal is not understood, though they are known to move large distances, often many hundreds of kilometres between years (DoE 2016). Furthermore, they can appear in semi-urban or urban landscapes and in minor stands or scattered trees in otherwise cleared (grazing) land). With such a mobile species there is no habitat attribute which reflect movement amenity. A fixed score of 25 is applied.

Absence of Threats

Documented threats for this species include (DoE 2016):

- Clearing resulting in loss of woodland habitat
- Small population size
- Habitat degradation
- Competition with aggressive rivals (e.g., Noisy Miner, etc).

Table 3.21 below assesses these threats across the SGP.

Table 3.21. An assessment of individual threats for Regent Honeyeater across the broad SGP

Threat	Scope	Severity	Score
Clearing resulting in loss of habitat	While not specially protected, clearing of riparian habitats is uncommon. Likely to affect less than 19% of the SGP area (score = 5).	No resident Regent Honeyeaters occur within the affected areas and none are expected to occur. Impacts on habitats and populations will be negligible (score = 5).	25
Small population size	N/A. This is not a threat that has a scope or severity relevant to this assessment.		N/A
Habitat degradation	All areas of possible Regent Honeyeater habitat within the modelled 'maybe' extent are within state forest or National park except	Based on historic trends habitats are unlikely to be significantly degraded over the next decade (score = 5).	25

	Long Swamp which represents < 20% of habitat extent (score = 5).		
Competition	All areas of potential habitat within the modelled extent are likely affected by competition (score = 1).	No populations are known or likely to inhabit the affected areas. The severity of impact is therefore negligible (score = 5).	5

3.2.7.3 Habitat Quality Scores

Habitat quality scores for Regent Honeyeater have been evaluated at sites representing suitable REs within the SGP. A summary of scores for each RE is provided in Table 3.22 with scores for individual sites provided in Appendix B.

Table 3.22. Summary of Habitat Quality Scores (out of 10) for Regent Honeyeater (*Anthochaera phrygia*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.25	6	4.90	6.63	5.99	0.61
11.3.27f	1	3.65	3.65	3.65	n/a
11.3.27i	4	5.04	6.36	5.63	0.55

3.2.8 Koala (Phascolarctos cinereus)

3.2.8.1 Likely Occurrence

In Queensland Koalas can be found from Atherton Tableland west of Cairns south to the NSW/QLD border and inland to central and western Queensland. The assessment areas are contained entirely within the Koala distribution.

Koalas occur in a diversity of habitats including temperate, sub-tropical and tropical forest, woodland and semi-arid communities, and sclerophyll forest, on foothills, plains and in coastal areas (Martin and Handasyde 1999; Martin et al. 2008). Koalas near the western edge of their range are often associated with watercourses though are not restricted to them (Melzer *et al.* 2000; Sullivan *et al.* 2003). Within the Brigalow Belt they occur at low densities, approximately 0.005 Koalas/ha and have thought to have declined by 30-40% in the last 20 years. (DAWE 2021e)

The SGP appears to be uniquely positioned across a transition zone of Koala abundance and habitat use (Figure 3.7). In the east Koalas are comparatively common (especially in the Wilkie Creek and Condamine River catchments) and frequent both riparian and non-riparian habitats, while they are rarely encountered in the west where they are largely associated with riparian vegetation (EcoSmart Ecology 2019b).

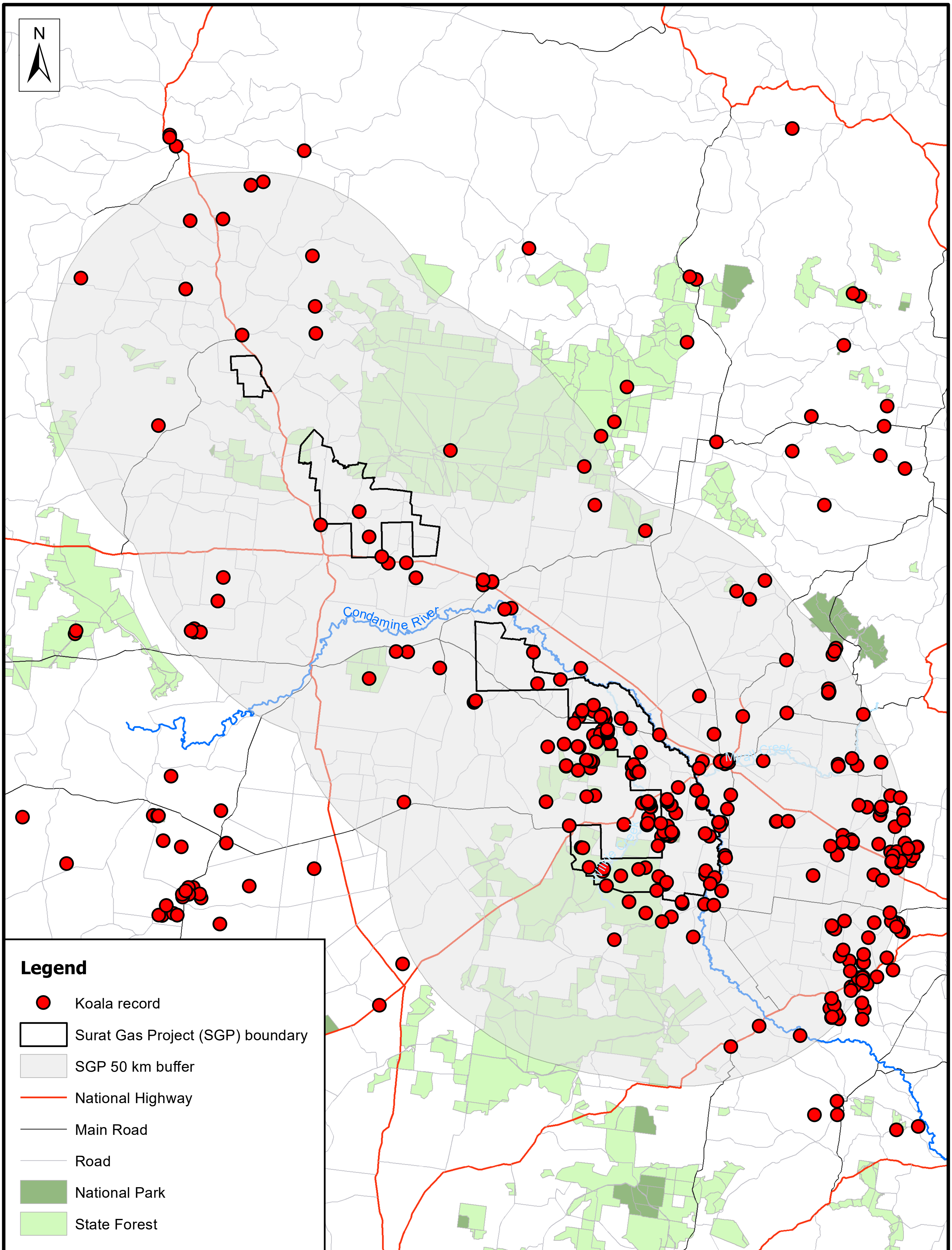

Figure 3.7

Koala records within 50 km of the SGP

Scale:

1:1,278,325

0 5 10 20 30 40
Kilometers

ecosmart ECOLOGY

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

This improved understanding of Koala values within the SGP has resulted in a more conservative approach to the list of regional ecosystems that should be considered 'Core Habitat Possible' (Table 3.23).

Table 3.23. Regional Ecosystems used to calculate Koala 'Core Habitat Possible'.

	Core Habitat Possible	General Habitat
Previous mapping (3D Environmental 2019; EcoSmart Ecology 2017)	11.3.2, 11.3.3, 11.3.4, 11.3.14, 11.3.17, 11.3.18, 11.3.25, 11.3.26, 11.3.27d and 11.3.27f	11.4.3, 11.4.3a, 11.5.1, 11.5.1a, 11.5.4, 11.5.20, 11.7.2, 11.7.4, 11.7.6, 11.7.7, 11.9.2 and 11.9.7
Refined (new) mapping (EcoSmart Ecology 2019a)	11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.14, 11.3.17, 11.3.18, 11.3.25, 11.3.26, 11.3.27, 11.4.3, 11.5.1, 11.5.4, 11.5.20, 11.7.4, 11.7.6, 11.9.2, 11.9.7, 11.9.10	11.5.21, 11.7.2, 11.7.7

3.2.8.2 Estimating Species Habitat Attributes

This section outlines and justifies scoring attributes for Koala habitat amenity. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Foraging, Shelter and Breeding Habitat

Habitat requirements for Koala are well understood and not complex. They forage, shelter and breed in the same habitat, and high value habitat is largely predicated on eucalypt density. However not all eucalypts are of equal value with some species favoured over others. Within the SGP favoured tree species include *E. camaldulensis, E. tereticornis, E. coolabah*, *E. populnea*, *E. crebra* and *E. chloroclada. Eucalyptus thozetiana* may have local importance, especially in the central and western areas of the SGP (M. Sanders *unpub. data*). Scoring the value of habitat for 'foraging' and 'shelter and breeding' was evaluated using the criteria in Table 3.24 below.

Table 3.24. Criteria for scoring 'forage' and 'shelter and breeding' habitat for Koala.

Abundance eucalypt trees* in T1 and T2 (No./ha)	0	1-50	51-100	101-150	151-200	200+
Score	0	5	10	15	20	25

* Excludes *Corymbia* and *Angophora*

Mobility Habitat

Koala's are largely sedentary and tend to confine movements to a small number of nearby trees within a day. Home ranges in low amenity habitats are much larger than in those containing high quality vegetation. Male home ranges at Blair Athol were estimated at 135 ha while females had a home range of 101 ha. This probably represents a good approximate for Koala home range within the SGP as vegetation and conditions around Blair Athol are comparable.

Dispersing individuals, mostly young males, can cover large distances with studies finding movements from natal grounds can be as much as 9 km, 10 km, 11 km and 16 km (DAWE 2021e and references therein). This can include crossing several kilometres of land with little vegetation.

Koalas therefore, are not heavily reliant on particular habitat types or structures for movement. Passage is undoubtably improved through habitats which have abundant foraging resources and the scoring in Table 3.24 can also be applied for Koala mobility.

Absence of Threats

The main processes threating to Koala populations and habitats are ongoing habitat loss and habitat fragmentation, vehicle strike, and predation by domestic/feral dogs. Drought and extreme heat, which will become more frequent and intense due to climate change may also threaten the species (DAWE 2021e).

All these threats have the potential to affect existing Koala populations across the entire SGP and the scope of threats is therefore estimated as 'Very High' (i.e., affecting 80-100% of the species population or habitat within the matter area). Evaluating the severity of impact is more difficult but based on historic declines of 30-40% and without evidence these impacts will abate, similar declines could be expected in the future. Over a ten-year window declines of 15-20% might be anticipated resulting in a 'Medium' impact severity. Using these estimates the SGP matter area receives an 'Absence of threats' score of 3.

However, vegetation along riparian corridors are frequently used by Koala (Melzer *et al* 2000, Sullivan *et al* 2003) in the west of their range. This might be due to several factors including improved leaf moisture and nutrient levels and/or better thermal refugia during extreme heat events. Some threats in these habitats may be less, and importantly, these vegetation types may be more important for the long-term persistence of populations. Threatening processes to Koala in these habitats (REs on Landzone 3) have been awarded a higher score of 6.

While the above estimate is based on threats across the entire matter area (i.e., the SGP), threat scope and threat severity may vary at a local property or area scale. This variability must be considered and accounted for when evaluating potential offset sites. It may be necessary to recalculate the threats, or used a fixed score, for both the impact and offset properties/habitat. This may be particularly important for loss of Koala habitat in large contiguous patches of vegetation where threats are likely less than evaluated here.

3.2.8.3 Habitat Quality Scores

Habitat quality scores for the Koala have been evaluated at sites representing suitable REs within the SGP except RE11.3.26, 11.9.2, 11.9.7 and 11.9.10. A summary of scores for each RE is provided in Table 3.25 with scores for individual sites provided in Appendix B.

Table 3.25. Summary of Habitat Quality Scores (out of 10) for Koala (*Phascolarctos cinereus*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.1	6	2.83	4.18	3.37	0.48
11.3.2	14	3.88	5.85	4.82	0.72
11.3.3	2	3.60	4.80	4.20	0.85
11.3.4	14	4.74	7.23	5.93	0.78
11.3.14	3	3.97	6.77	5.33	1.40
11.3.17	6	3.07	4.98	3.91	0.82
Brigalow Regrowth (11.3.17)	4	1.73	2.67	2.16	0.44
11.3.18	4	4.31	6.41	5.40	0.86
11.3.25	6	5.64	7.97	6.74	0.86
11.3.27f	1	5.49	5.49	5.49	n/a
11.3.27i	4	5.28	7.20	6.17	0.85
11.4.3	1	2.78	2.78	2.78	n/a
Brigalow Regrowth (11.4.3)	1	2.86	2.86	2.86	n/a
11.5.1	5	5.43	6.62	5.97	0.51
11.5.1 (regrowth)	2	2.76	2.90	2.83	0.09
11.5.4	6	3.53	5.75	4.85	0.87
11.5.20	7	2.93	5.93	4.61	1.35
11.7.4	8	3.33	7.04	5.92	1.14
11.7.6	5	3.57	5.63	5.07	0.86
11.7.6 (regrowth)	1	3.70	3.70	3.70	n/a

3.2.9 Greater Glider (Petauroides volans)

3.2.9.1 Likely Occurrence

The Greater Glider extends from the Windsor Tableland in north Queensland south to Wombat State Forest in central Victoria (Woinarski *et al* 2014). While the SGP and the associated areas entirely overlap with the distribution of the Greater Glider, they are located at the species western extremity. West of Toowoomba the species becomes increasingly patchy, often apparently absent from otherwise seemingly suitable habitat.

Greater Gliders are predominately restricted to eucalypt forests and woodlands, peaking in abundance in taller, montane, moist eucalypt forests with large old trees (Andrews *et al.* 1994; Kavanagh 2000; Eyre 2004; van der Ree *et al.* 2004; Vanderduys *et al.* 2012). In areas west of the Great Dividing Range, they are found in low woodlands (McKay 2008) but being hollow-roosting obligates require large hollows.

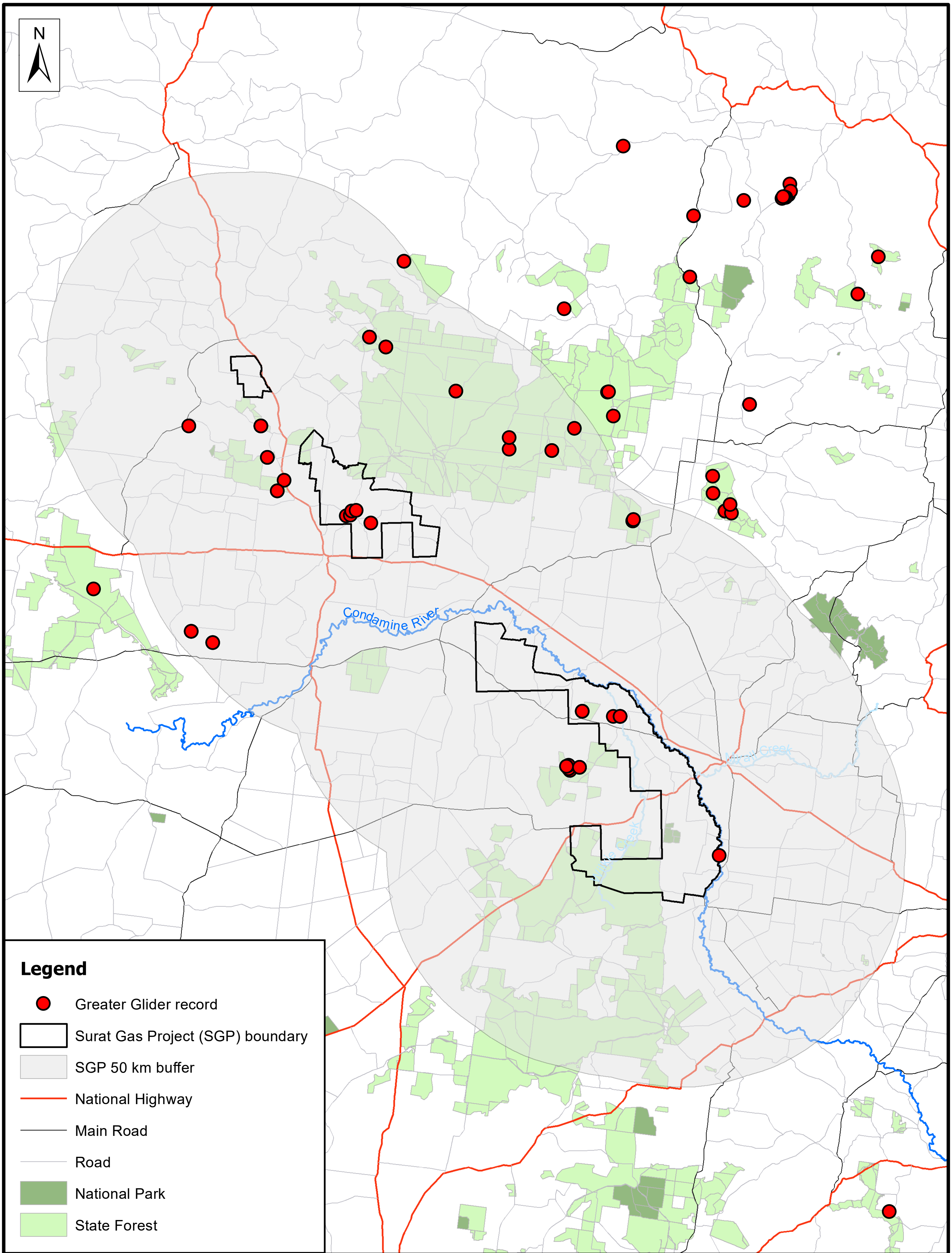

Figure 3.8

Greater Glider records within 50 km of the SGP

Scale:

1:1,278,325

0 5 10 20 30 40

Kilometers

ecosmart ECOLOGY

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

Based on experiential and documented knowledge of the species habitat requirements, mapping rules were defined to identify areas of 'core habitat' for the SGP (EcoSmart Ecology 2017). Regional Ecosystems 11.3.4, 11.3.25 and 11.3.27 (incorrectly listed as 11.3.26) were recognised as important habitats. Ongoing work and improved knowledge of the species within the SGP suggest an addition two REs should be recognised as 'core habitat possible': 11.7.6 and 11.7.7. However, habitat amenity will be influenced by hollow availability with some vegetation patches unlikely to support the species. This should be a particular consideration for 11.7.6 and 11.7.7 which often lacks old-growth hollow-bearing trees due to historic logging.

3.2.9.2 Estimating Species Habitat Attributes

This section outlines and justifies scoring attributes for Greater Glider habitat amenity. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Quality of Foraging Habitat

Greater Gliders are described as having a strictly 'eucalyptus' diet but will also occasionally take flowers and rarely *Acacia* phyllodes and Mistletoe leaves (Lindenmeyer 2002; Kavanagh and Wheeler 2004; Woinarski *et al* 2014). Studies have found a preference for young leaves or select eucalypt species, with selection likely related to leaf nutrient concentration (Kavanagh and Lambert 1990; Lindenmeyer 2002; Eyre 2006). Dietary selection in the southern Brigalow Belt is poorly understood with a single study finding foraging animals most often in *E. moluccana, E. fibrosa* and *Corymbia citriodora* (Smith *et al* 2007). A study of Greater Gliders across the broader southeast Queensland region (including the Brigalow Belt Bioregion) also identified *E. tereticornis* and *E. citriodora* as predictors of Greater Glider presence in drier forests (Eyre 2006). Arrow surveys have frequently located Greater Gliders in old-growth riparian stands of *E. tereticornis*, sometimes forest dominated by *C. citriodora*, less frequently *E. populnea* and rarely *E. moluccana* (M. Sanders *pers. obs.*). In contrast Comport *et al* (1996) found Greater Gliders showing a preference for *E. acmenoides* over other eucalypts, which included *E. tereticornis* and *C. citriodora*, despite other eucalypts having higher nutrient content.

Without a detailed understanding of leaf nutrient, toxicity and fibre content it is difficult to predict and score foraging amenity for Greater Glider within the SGP. Further, the SGP is located within a region where large hollows are in low abundance and this, rather than foraging resources, may be the limiting factor in determining habitat amenity for Greater Glider (Smith *et al* 2007).

Many studies have identified tree size as being important for Greater Gliders. Smith *et al.* (2007) found gliders only in trees with a DBH of > 20 cm and most in trees 30-70 cm in size; use of trees < 30 cm were less than expected based on tree availability. Other studies have also noted tree size (Kavanagh and Lambert 1990; Eyre 2006) or leaf biomass (Davey 1984; Comport *et al* 1996) as an important predictor of Greater Glider activity. Observations within and surrounding the SGP seem to support this correlation with many records from vegetation dominated by exceptionally large trees (M. Sanders *pers. comm.*) or associated with tree species such as *E. camaldulensis, E. tereticornis, E. fibrosa* and *C. citriodora* (Smith 2006; M. Sanders *pers. obs.*) which attain a greater size in the broader landscape. Considering these factors forage habitat has been scored by comparing the abundance of large eucalypts against the benchmark for each RE as in Table 3.26. This is more measurable in the field than leaf nutrient content. It is noted this scoring system may have co-dependence with 'shelter and breeding' as suitably large hollows are also correlated to tree size (Smith *et al* 2007).

Table 3.26. Criteria for scoring 'forage' habitat for Greater Glider

Number of large Eucs compared to benchmark (as a percentage)^	≤10	>10-30	>30-50	>50-70	>70-90	≥90
Score	0	5	10	15	20	25

^ as per the Biocondition Methodology; includes *Corymbia*, *Angophora* and *Eucalyptus*

Quality of Shelter and Breeding Habitat

The sheltering and breeding requirements of Greater Gliders are relatively well understood. They require large old-growth trees with abundant large hollows. Both live and dead trees will be used but most den trees are living (Kavanagh and Wheeler 2004). Preferred hollows are typically higher in the canopy and deeper hollows with a large internal cavity are preferred over shallow hollows (Lindenmayer 2002). Hollow entrance size is poorly documented but likely around 18 cm (Goldingay 2011).

In south-east Queensland the Greater Glider is often absent from sites supporting less than six hollow-bearing trees per hectare (Lindenmayer 2002). Studies in Barakula, a state forest adjoining the SGP, found female Greater Gliders inhabited areas with, on average, 3.8 den trees per hectare while male home ranges had far fewer, on average 0.9 den trees per hectare (Smith *et al* 2007). Males used slightly more hollow-bearing trees (4-20, average 11) than females (6-18, average 10). The scoring system below is based on this work and evaluates habitats based on the number of trees containing hollows > 30cm diameter.

Table 3.27. Criteria for scoring 'shelter and breeding' habitat for Greater Glider

Trees (incl. stags) containing hollows > 20cm in diameter (No./ha)	0	1-3	4-5	6-7	8-9	>9
Score	0	5	10	15	20	25

Quality of Habitat required for Mobility

Greater Gliders have little body fat and animals can loose 'condition' quickly (Lindenmayer 2002). Rapid long-distant movements by the species are unlikely, especially across habitats where there are few hollows for 'stop-overs'. This may explain their low dispersal through fragmented and/or heavily logged landscapes where hollow-bearing tree density has been reduced.

In contrast to most other glider species, Greater Gliders spend a significant portion (40%) of their time resting (Comport *et al* 1996; Lindenmayer 2002). They are also much slower to move and more reluctant to glide than other Australian gliding mammals (Cunningham *et al* 2004; M. Sanders *pers. obs.*). Unlike arboreal species such as the Brushtail Possum, they are rarely observed venturing to the ground.

In addition to hollow density, these behaviours suggest canopy density may be important for facilitating Greater Glider movement. Despite their ability to glide large distances if needed, often exceeding 50 m (Lindenmayer 2002), overlapping canopies which allow animals to efficiently move without the need to glide may be more amenable. This may affect habitat selection, with Greater Gliders being rare in comparatively open woodlands despite tall forage trees and abundant hollows. However dense regrowth forest is believed to impair the movement of Greater Gliders (Lindenmayer 2002).

The scoring below, which reflects canopy cover, is based on canopy intercept data collected as per the BioCondition Assessment Manual (Eyre *et al* 2015).

Table 3.28. Criteria for scoring 'Quality of habitat for mobility' for the Greater Glider

% Canopy Cover (T1+T2 intercept)*	0-39	40-49	50-59	60-69	70-79	80+
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

Absence of Threats

Known threats to the Greater Glider include (Woinarski *et al* 2012; DOE 2015):

- Habitat loss and subsequent fragmentation
- Timber logging/production
- Inappropriate fire regime
- Timber production
- Barbed wire fencing entanglement
- Climate change

While the species is thought to have declined by 30% across its range over a 22-year period (DOE 2015), population trends in the southern Brigalow Belt are poorly documented or understood. Historical habitat loss, fragmentation and timber production are likely to have had a significant impact on large portions of Greater Glider habitat within the SGP and surrounding areas. With the federal listing of the species and greater vegetation clearing controls, these threats should abate, at least theoretically.

Greater Gliders are a 'cold-adapted' species that becomes heat-stressed at temperatures above 30°C. While animals salivate and moisten their fur to dissipate heat, these strategies to not appear effective over longer periods. Temperatures, and in particular prolonged periods of extreme heat, are predicted to increase due to climate change. This impact has the potential to significantly affect the entire population within the SGP and immediate surrounds.

Being sensitive to fragmentation, most Greater Glider records within and surrounding the SGP are located in large contiguous patches of forest (see Figure 3.8). These areas are more susceptible to wildfire, and historic fire mapping shows the frequency and extent of wildfires are increasing (Appendix C). This is consistent with climate change predictions and wildfires have the potential to severely affect all habitats throughout the SGP.

Of all the potential impacts climate change, and the associated change in fire regimes, is likely to pose the greatest future risk to populations and habitats within the SGP and surrounds. The scope of these impact is 'very high' with all areas likely affected. However, assessing the impact severity is difficult. Based on the extent and severity of historic wildfire fires in the last two decades, it is possible impacts could affect up to 40% of the population; a moderate impact severity. These estimates result in a 'absence of threats' score of 3 across the SGP.

It should be noted that the above assessment considers the SGP in its entirety. Some patches may be more resilient to fire and provide some buffering to extreme heat conditions. The score may not reflect individual areas of habitat or populations.

Table 3.29. Criteria for scoring 'Quality of habitat for mobility' for the Greater Glider

% Cover (T2+S1 intercept)*	0-39	40-49	50-59	60-69	70-79	80+
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

3.2.9.3 Habitat Quality Scores

Habitat quality scores for the Greater Glider have been evaluated at sites representing suitable REs within the SGP except RE11.3.26. A summary of scores for each RE is provided in Table 3.30 with scores for individual sites provided in Appendix B.

Table 3.30. Summary of Habitat Quality Scores (out of 10) for Greater Glider (*Petauroides volans*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.4	14	2.57	6.04	3.87	1.09
11.3.25	6	3.92	6.85	5.76	1.08
11.3.27f	1	2.77	2.77	2.77	n/a
11.3.27i	4	4.36	5.28	4.70	0.40
11.7.6	5	3.57	5.63	4.91	0.79
11.7.7	5	0.00	6.78	4.54	2.68

3.2.10 Southern Long-eared Bat (*Nyctophilus corbeni*)

3.2.10.1 Likely Occurrence

Records of Southern Long-eared Bat occur to the north, south and west of the SGP (Figure 3.9). However the species is absent from open and modified habitats on the Condamine River flood plains which stretch along the central-east and south-east boundary of the SGP. Suitable habitat east of the SGP is only present in the very north (i.e, near Barakula State Forest). Therefore, while large areas of suitable habitat occur within the SGP, it is situated at the eastern distributional limit of the species.

Within its distribution the species tends to be absent from smaller remnants of vegetation and this may indicate a requirement for larger more continuous intact vegetation (Turnbill and Ellis 2006). The species rarely uses areas of post wild-fire regrowth or open habitats (Law *et al* 2016). In general, *N. corbeni* appears most abundant where the vegetation has a distinct canopy and a dense, cluttered understorey layer.

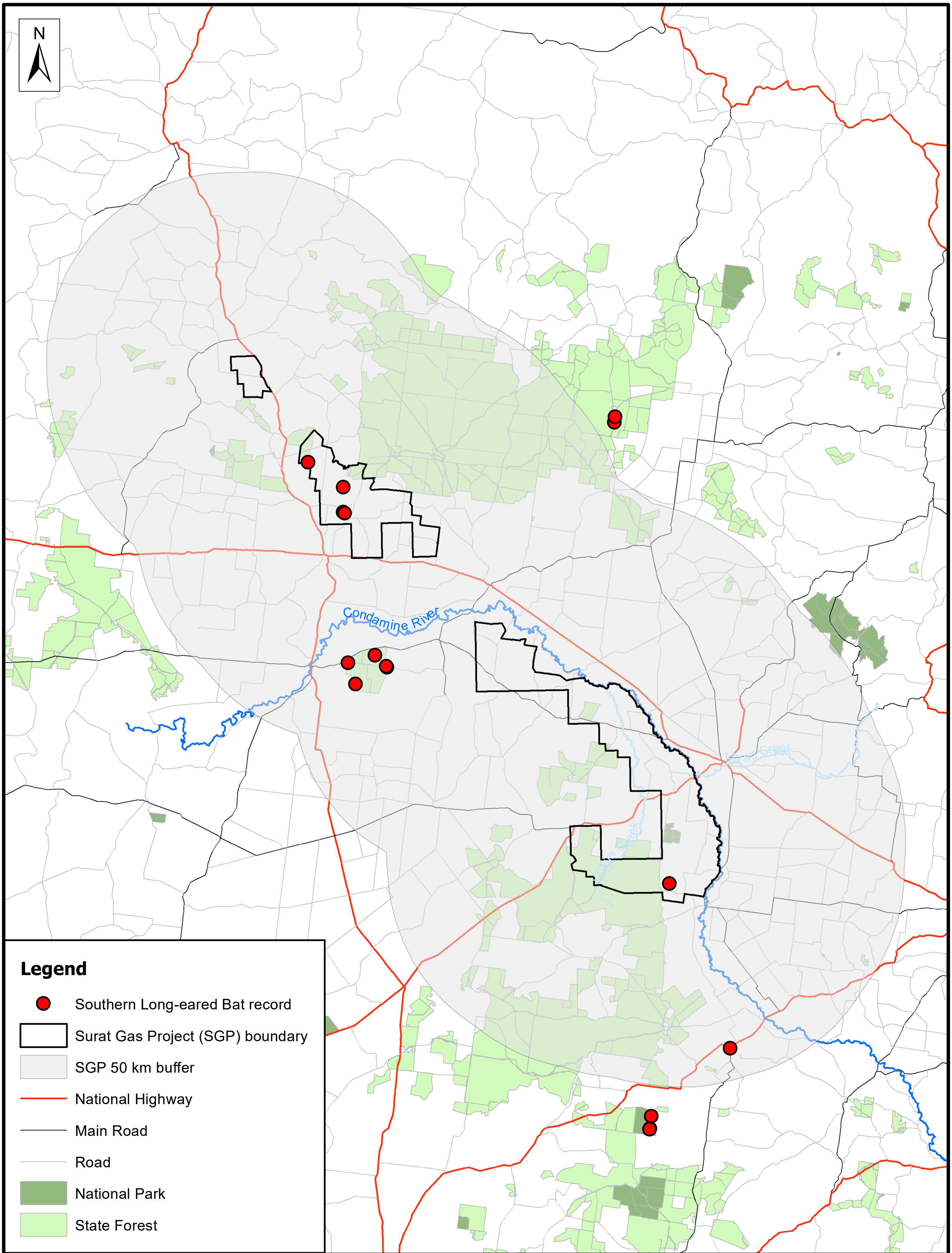

Figure 3.9

Southern Long-eared Bat records within 50 km of the SGP

Scale:

1:1,278,325

0 5 10 20 30 40

Kilometers

Client: Arrow Energy | **Project:** SGP OAMP BioCondition and HQS Report

Published research into the ecology of *N. corbeni* and updated records of the species in the SGP region suggest the existing habitat suitability rules are inadequate. Suitable habitat (i.e., 'Core Habitat Possible') should include the following REs when they are located within a contiguous patch of remnant vegetation (including accumulative area where patches are separated by less than 200 m) greater than 5,000 ha: 11.3.14, 11.3.18, 11.5.1, 11.5.4, 11.5.20, 11.5.21, 11.7.4, 11.7.6, 11.7.7 and 11.9.10. Regional Ecosystems 11.3.25 and 11.3.27 were previously considered 'Core Habitat Possible' but should be reassigned to 'General Habitat' unless they contribute to a larger continuous vegetation patch.

3.2.10.2 Estimating Species Habitat Attributes

This section outlines and justifies scoring attributes for *N. corbeni* habitat amenity. The scoring system is to be used for comparative purposes only and does not reflect likely occurrence.

Quality of 'Forage' Habitat

The diet of Southern Long-eared Bats is not well understood with some studies suggesting a diverse range of invertebrate prey but possible seasonal preferences (Law *et al* 2016) while others a predominantly Lepidopteran (moth) diet (Vestjens and Hall 1977). Direct measurement of prey abundance is a difficult ecological attribute to sample and score, however the species possesses specialised ecological traits which favouring slow, manoeuvrable flight and prey detection in dense vegetation (Denzinger and Schnitzler 2013; Law *et al* 2016). This provides ecological separation from many other echolocating bat species.

Measuring vegetation density can be achieved using data collected as part of the BioCondition Assessment methodology and should focus on the sub-canopy and shrub data.

Table 3.31. Criteria for scoring 'forage' habitat amenity for the Southern Long-eared Bat

% sub-Canopy Cover (T2+S1/S2 intercept)*	0-30	>30-40	>40-50	>50-60	>60-70	>70
Score	0	5	10	15	20	25

* As estimated using the BioCondition Assessment Methodology (Eyre *et al* 2015)

Quality of 'Shelter and Breeding" Habitat

Law *et al* (2016, 2018) found *Nyctophilus corbeni* roosts most frequently in dead eucalypts, followed by Bulloak (*Allocasuarina luehmannii*), dead cypress (*Callitris sp.*) and other unknown dead trees. Roost trees are more frequently located in comparatively dense vegetation, but roost preference seems to be influenced by hollow availability rather than a preference for any particular tree species (Law *et al* 2016). Most roost trees are < 40cm DBH and, despite being common in the landscape, hollows in larger trees (e.g., *E. camaldulensis*) are not utilised. Small hollows are the most utilised roost structure, though roosting in fissures or under bark is also common. Typically individuals do not use a roost location over sequential nights preferring to regularly move between roosts.

Sampling or estimating the direct abundance of possible roosts for *N. corbeni* is problematic as they are often small and inconspicuous. A possible surrogate variable is the abundance (per hectare) of dead trees between 10 and 40 cm DBH. These are recognised as important for predicting high value habitat (Law *et al* 2016, 2018). Sampling in NSW found dead tree density in occupied patches to average 91/ha (pregnant and lactating females) and 138/ha (males)

(Law *et al* 2016). No existing *BioCondition Methodology* attribute measures dead tree abundance and, as such, all future offset surveys must use this measure as a new attribute.

Table 3.32. Criteria for scoring 'shelter and breeding' habitat amenity for the Southern Long-eared Bat

No. dead trees (10-40cm DBH/ha)	<40	40-50	>50-60	>60-70	>70-80	>80
Score	0	5	10	15	20	25

Quality of Habitat required for Mobility

Southern Long-eared Bats typically forage up to about 4 km from their roost, though individuals have been rarely captured up to 7 km from roost. Average forage distance seems to be around 1 to 2 km (Law *et al* 2016).

Available evidence suggests the species is reluctant to move into open habitats including wild-fire regrowth (Law *et al* 2016, 2018). This may, in part, explain why most records are associated with larger continuous intact vegetation (Turnbill and Ellis 2006). Further, minor fragments and linear strips of native vegetation are vulnerable to understorey damage and loss of dead trees, especially where combined with grazing. Combining these two attributes (Table 3.33), connectivity and habitat structure, probably best describe the quality of habitat for movement.

Table 3.33. Criteria and matrix for scoring 'mobility' habitat amenity for Southern Long-eared Bats (*Nyctophilus corbeni*)

		Connectivity Score*			
		0	2	4	5
'Forage' and 'shelter/breeding' amenity (average)	<5	0	0	5	10
	5-10	0	5	10	15
	<10-15	5	5	10	15
	<15-20	5	10	15	20
	>20	10	15	20	25

* As assessed and scored using the *BioCondition Assessment Methodology*

Absence of Threats

The main threats the Southern long-eared bat are:

- Habitat loss and fragmentation from clearing (Reardon 2012)
- Degradation of habitat from grazing
- Habitat loss and vegetation thinning from silviculture activities (Law *et al* 2016)
- Habitat loss and degradation from wildfire (Turbill *et al* 2008)

Survey data suggest that large, intact remnants of suitable habitat are required to support populations (Turbill and Ellis 2006; Turbill *et al* 2008). With more than 75% of habitat cleared in some parts of its range, land clearing and fragmentation continue to threaten this species

(Duncan *et al* 1999). Increased competition for hollows is an example of a flow-on impact from fragmentation (Reardon 2012).

Being associated with large continuous intact patches of vegetation, *N. corbeni* habitat within the SGP is most likely associated with State Forests; much of the surrounding landscape on private land has been cleared or substantially modified. Some habitat loss from clearing continues in state forest associated with gas harvesting projects, while clearing is also possible on private lands for a variety of purposes. It is difficult to estimate the likely extent of clearing activities in the near future, but an estimate of < 19% seems reasonable. Grazing is uncommon in state forests and, when present, usually low intensity with minor impacts. Logging and in particular wildfire, have the greatest potential to affect broad areas of *N. corbeni* habitats. The possibility and extent of wildlife is particularly difficult to estimate but based on historic trends fires might affect 20-39% of habitat within the SGP. An estimate of each threat is provided in the table below, with a lowest score of 5 related to ongoing clearing activities.

Table 3.34. An assessment of individual threats for *Nyctophilus corbeni* across the broad SGP

Threat	Scope	Severity	Score
Ongoing loss and fragmentation of habitats	Difficult to estimate, but likely < 20% of the SGP affected in next 10 years (score = 5).	Within the scope area, all habitat and populations are likely lost (score = 1).	5
Degradation from grazing	Most retained habitats within State Forest where grazing is uncommon, some grazing possible in suitable habitat private lands. Possibly 20-39% of area affected (score = 4).	Retained habitats generally do not support high intensity grazing and impacts over next few decades on affected areas likely to be very low (score = 5).	20
Habitat loss and degradation from logging and vegetation thinning	Extent difficult to predict. Estimated as low (20-29%; score = 4).	Within affected areas this impact might reduce or degrade 11-39% of the species habitat/population within the next decade (score = 3).	12
Habitat loss and degradation from wildfire	Future extent of wildfires across the SGP difficult to predict. Based on existing trends likely to affect 20-39% of suitable habitat (score = 2).	Within wildfire areas it is likely 80-100% of the habitat or population would be detrimentally affected (score = 5).	10

3.2.10.3 Habitat Quality Scores

Habitat quality scores for the Southern Long-eared Bat have been evaluated at sites representing suitable REs within the SGP except RE11.9.10. A summary of scores for each RE is provided in Table 3.35 with scores for individual sites provided in Appendix B.

Table 3.35. Summary of Habitat Quality Scores (out of 10) for Southern Long-eared Bat (*Nyctophilus corbeni*)

Regional Ecosystem	N	Min	Max	Mean	Std Dev
11.3.14	3	1.53	4.83	3.49	1.74
11.3.18	4	2.30	5.89	3.76	1.70
11.5.1	5	4.31	6.63	5.49	0.96
11.5.4	6	3.21	4.63	3.76	0.62
11.5.20	7	2.41	6.81	4.49	1.93
11.5.21	1	6.08	6.08	6.08	n/a
11.7.4	8	3.61	7.52	5.87	1.07
11.7.6	5	3.05	6.11	5.19	1.22
11.7.7	5	5.37	7.28	6.01	0.79

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Appendix A:
HQS Data Gap Analysis

HQS site gap analysis

Ground verified ESU / Regional Ecosystem	Area (ha)	Total number of survey sites required (as supplied by Arrow)	Number of sites completed in previous works (existing data)[#]	Balance required
11.3.1 Remnant	175.23	4	2	2
11.3.14 Regrowth	98.43	3	0	3
11.3.14 Remnant	325.12	4	2	2
11.3.17 Regrowth	30.67	2	0	2
11.3.17 Remnant	128.64	4	0	4
11.3.18 Regrowth	43.52	2	0	2
11.3.18 Remnant	412.9	4	5	0
11.3.2 Disturbed	34.51	2	0	2
11.3.2 Regrowth	558.99	5	0	5
11.3.2 Remnant	463.75	4	0	4
11.3.25 Disturbed	4.78	2	0	2
11.3.25 Regrowth	0.35	2	0	2
11.3.25 Remnant	1413.39	6	9	0
11.3.26 Remnant	25.19	2	0	2
11.3.27 Remnant	678.7	5	4	1
11.3.3 Remnant	26.81	2	0	2
11.3.4 Disturbed	88.31	3	0	3
11.3.4 Regrowth	131.24	4	0	4
11.3.4 Remnant	1242.3	6	2	4
11.4.3 Regrowth	68.32	3	2	1
11.4.3a	15.059	2	0	2
11.4.3 Remnant	410.76	4	3	1
11.5.1 Disturbed	790.21	5	0	5
11.5.1 Regrowth	7762.68	6	6	0
11.5.1 Remnant	34442.22	6	10	0
11.5.20 Disturbed	26.38	2	0	2
11.5.20 Regrowth	175.34	4	2	2
11.5.20 Remnant	6292.43	6	4	2
11.5.21 Disturbed	1.02	2	0	2
11.5.21 Remnant	2217.39	6	1	5
11.5.4 Regrowth	0	0	2	0
11.5.4 Remnant	3470.04	6	6	0
11.7.2 Remnant	172.87	4	3	1
11.7.4 Disturbed	1.11	2	0	2
11.7.4 Regrowth	752.32	5	4	1
11.7.4 Remnant	13072.75	6	7	0
11.7.5 Remnant	460.63	4	1	3
11.7.6 Regrowth	0.97	2	2	0

Ground verified ESU / Regional Ecosystem	Area (ha)	Total number of survey sites required (as supplied by Arrow)	Number of sites completed in previous works (existing data)#	Balance required
11.7.6 Remnant	1255.62	6	4	2
11.7.7 Regrowth	10.62	2	0	2
11.7.7 Remnant	9502.91	6	6	0
Regrowth Brigalow (<15yrs)	41.71	2	0	2
Regrowth Brigalow (>15yrs)	298.75	4	0	4
Totals	**87,109.89**	**161**	**87**	**74**

Data from sites completed in 3D Environmental 2013, EcoSmart Ecology 2017, 2018 and 2019

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Appendix B: Habitat Quality Scores – Site Summary Data

Collared Delma (*Delma torquata*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.2	S1	2.18	1.95	2.8	6.93
	S2	1.84	1.95	1.2	4.99
	S3	1.58	1.65	0.8	4.03
	S7	1.71	1.35	0.8	3.86
	S8	1.39	1.05	1.2	3.64
	CS10	1.99	0.30	2.8	5.09
	CS16	2.21	0.30	2.8	5.31
	RR1	1.76	0.60	0.8	3.16
	RR2	1.78	0.30	1.2	3.28
	RR4	0.96	0.60	0.8	2.36
	RR8	1.67	0.30	0.8	2.77
	CN1	2.29	0.30	1.6	4.19
	CN11	2.31	1.50	2.8	6.61
	CN12	2.23	1.50	0.8	4.53
11.7.2	AG253	1.91	2.55	2.8	7.26
	AG293	2.10	2.55	3	7.65
	AE68	2.42	2.40	3.4	8.22
	EPB48	2.29	2.55	3.2	8.04
11.7.4	CS8	2.01	0.00	2.4	4.41
	AE22	2.27	2.85	0.8	5.92
	AE41	1.95	2.85	3.8	8.60
	AE47	1.88	2.85	3.4	8.13
	AE 50	2.01	2.85	2.6	7.46
	AE66	2.06	2.70	3.8	8.56
	AE70	2.10	2.10	3.8	8.00
	GBS1	2.87	2.85	1.6	7.32

Yakka Skink (*Egernia rugosa*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.1	CS2	1.46	1.35	2.88	5.69
	CN10	2.44	0.90	2.88	6.22
	RR10	2.12	0.30	2.48	4.90
	RR11	1.91	0.30	0.68	2.89
	RR12	1.99	0.00	2.28	4.27
	AE06	1.67	1.35	0.88	3.90
11.3.2	S1	2.18	1.95	2.68	6.81
	S2	1.84	1.95	1.68	5.47
	S3	1.58	1.65	1.48	4.71
	S7	1.71	1.35	1.08	4.14
	S8	1.39	1.05	1.88	4.32
	CS10	1.99	0.30	2.48	4.77
	CS16	2.21	0.30	2.48	4.99
	RR1	1.76	0.60	0.68	3.04
	RR2	1.78	0.30	1.28	3.36
	RR4	0.96	0.60	0.88	2.44
	RR8	1.67	0.30	0.68	2.65
	CN1	2.29	0.30	1.28	3.87
	CN11	2.31	1.50	2.28	6.09
	CN12	2.23	1.50	0.68	4.41
11.3.3	CS19	1.56	0.60	1.28	3.44
	CS21	1.56	0.60	0.88	3.04
11.3.4	CN2	1.73	1.73	1.68	5.13
	CN3	1.28	1.43	0.88	3.58
	CN4	1.33	1.43	2.68	5.44
	CN5	1.52	1.43	0.88	3.82
	CN15	1.59	2.40	1.28	5.27
	CN16	1.80	2.40	1.28	5.48
	RR3	1.41	0.90	0.48	2.79
	CS12	1.65	0.60	0.88	3.13
	CS13	1.97	0.60	1.88	4.45
	CS14	1.50	0.60	0.68	2.78
	CS17	2.14	0.60	0.48	3.22
	CS20	2.25	0.30	0.48	3.03
	GBS42	1.71	1.65	0.88	4.24
	GBS47	1.52	3.00	1.68	6.20
11.3.14	CS4	1.73	1.80	2.68	6.21
	CS9	1.33	0.00	2.08	3.41
	AE17	1.43	1.80	0.48	3.71
11.3.17	CS1	2.19	1.35	2.28	5.82
	CS3	2.10	1.35	0.48	3.93
	RR5	2.36	0.30	2.48	5.14
	RR6	2.29	0.30	2.68	5.27
	RR7	1.93	0.30	2.68	4.91
	RR9	1.84	0.30	1.28	3.42

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.18	CN6	1.97	0.30	3.08	5.35
	AE26	1.82	1.95	0.88	4.65
	AE32	1.20	0.90	0.88	2.98
	AE42	1.24	2.85	0.88	4.97
11.5.1	CN13	2.46	1.35	1.68	5.49
	AE20	1.85	2.85	0.68	5.38
	AE24	1.67	1.95	1.28	4.90
	AE46	1.78	2.85	3.08	7.71
	AE73	2.01	2.10	2.48	6.59
11.5.4	AE02	1.91	0.90	1.08	3.89
	AE03	2.19	2.10	0.88	5.17
	AE10	1.91	1.05	0.48	3.44
	AE11	2.25	1.05	0.68	3.98
	AE12	2.33	2.10	0.48	4.91
	AE55	1.89	0.90	1.68	4.47
11.5.20	CS5	1.67	0.60	0.88	3.15
	CS6	1.93	2.85	2.08	6.86
	CS7	1.74	0.60	0.48	2.82
	CN7	1.91	0.30	2.48	4.69
	AE58	2.36	2.85	1.08	6.29
	AE59	1.84	2.85	2.08	6.77
	AE60	2.27	2.85	2.48	7.60
11.5.21	GBS15	1.78	2.70	0.68	5.16
11.7.4	CS8	2.01	0.00	1.48	3.49
	AE22	2.27	2.85	0.88	6.00
	AE41	1.95	2.85	2.08	6.88
	AE47	1.88	2.85	2.88	7.61
	AE 50	2.01	2.85	1.68	6.54
	AE66	2.06	2.70	2.88	7.64
	AE70	2.10	2.10	2.68	6.88
	GBS1	2.87	2.85	1.28	7.00
11.7.5	GBS12	2.40	2.70	1.48	6.58
11.7.6	AE28	2.04	2.40	1.88	6.32
	AE36	1.65	1.20	2.88	5.73
	EPB47	1.84	3.00	1.48	6.32
	EPB51	1.91	3.00	1.88	6.79
	EPB58	1.73	3.00	2.48	7.21
11.7.7	N3	2.27	2.10	3.08	7.45
	AE21	1.97	1.95	0.48	4.40
	AE38	2.38	2.70	2.08	7.16
	AE62	2.23	2.40	1.88	6.51
	AE69	2.36	2.70	2.28	7.34

Dunmall's Snake (*Glyphodon dumnalli*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.1	CS2	1.46	1.35	3.48	6.29
	CN10	2.44	0.90	3.48	6.82
	RR10	2.12	0.30	2.88	5.30
	RR11	1.91	0.30	0.48	2.69
	RR12	1.99	0.00	2.88	4.87
	AE06	1.67	1.35	0.48	3.50
11.3.2	S1	2.18	1.95	2.88	7.01
	S2	1.84	1.95	1.08	4.87
	S3	1.58	1.65	0.48	3.71
	S7	1.71	1.35	0.48	3.54
	S8	1.39	1.05	1.08	3.52
	CS10	1.99	0.30	3.48	5.77
	CS16	2.21	0.30	3.48	5.99
	RR1	1.76	0.60	0.48	2.84
	RR2	1.78	0.30	1.08	3.16
	RR4	0.96	0.60	0.48	2.04
	RR8	1.67	0.30	0.48	2.45
	CN1	2.29	0.30	1.08	3.67
	CN11	2.31	1.50	2.88	6.69
	CN12	2.23	1.50	0.48	4.21
11.3.14	CS4	1.73	1.80	3.48	7.01
	CS9	1.33	0.00	2.28	3.61
	AE17	1.43	1.80	0.48	3.71
11.3.17	CS1	2.19	1.35	2.88	6.42
	CS3	2.10	1.35	0.48	3.93
	RR5	2.36	0.30	3.48	6.14
	RR6	2.29	0.30	3.48	6.07
	RR7	1.93	0.30	2.28	4.51
	RR9	1.84	0.30	0.48	2.62
11.3.18	CN6	1.97	0.30	2.88	5.15
	AE26	1.82	1.95	0.48	4.25
	AE32	1.20	0.90	0.48	2.58
	AE42	1.24	2.85	0.48	4.57
11.4.3	S6	2.06	0.60	2.68	5.34
	AE01	2.42	2.10	2.88	7.40
	AE45	2.16	0.90	3.48	6.54
	AE74	1.54	0.30	1.28	3.12

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.5.1	CN13	2.46	1.35	1.68	5.49
	AE20	1.85	2.85	0.48	5.18
	AE24	1.67	1.95	0.48	4.10
	AE46	1.78	2.85	3.48	8.11
	AE73	2.01	2.10	3.48	7.59
11.5.4	AE02	1.91	0.90	0.48	3.29
	AE03	2.19	2.10	0.48	4.77
	AE10	1.91	1.05	0.48	3.44
	AE11	2.25	1.05	0.48	3.78
	AE12	2.33	2.10	0.48	4.91
	AE55	1.89	0.90	1.68	4.47
11.5.20	CS5	1.67	0.60	0.48	2.75
	CS6	1.93	2.85	2.88	7.66
	CS7	1.74	0.60	0.48	2.82
	CN7	1.91	0.30	3.48	5.69
	AE58	2.36	2.85	1.08	6.29
	AE59	1.84	2.85	2.88	7.57
	AE60	2.27	2.85	3.48	8.60
11.5.21	GBS15	1.78	2.70	0.48	4.96
11.7.2	AG253	1.91	2.55	1.68	6.14
	AG293	2.10	2.55	2.88	7.53
	AE68	2.42	2.40	3.48	8.30
	EPB48	2.29	2.55	2.88	7.72
11.7.4	CS8	2.01	0.00	1.68	3.69
	AE22	2.27	2.85	0.48	5.60
	AE41	1.95	2.85	2.28	7.08
	AE47	1.88	2.85	3.48	8.21
	AE 50	2.01	2.85	1.68	6.54
	AE66	2.06	2.70	3.48	8.24
	AE70	2.10	2.10	2.28	6.48
	GBS1	2.87	2.85	1.08	6.80
11.7.6	AE28	2.04	2.40	2.28	6.72
	AE36	1.65	1.20	3.48	6.33
	EPB47	1.84	3.00	1.68	6.52
	EPB51	1.91	3.00	2.28	7.19
	EPB58	1.73	3.00	3.48	8.21
11.7.7	N3	2.27	2.10	3.48	7.85
	AE21	1.97	1.95	0.48	4.40
	AE38	2.38	2.70	2.88	7.96
	AE62	2.23	2.40	2.28	6.91
	AE69	2.36	2.70	2.88	7.94

Squatter Pigeon (*Geophaps scripta scripta*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.2	S1	2.18	1.95	0.50	4.63
	S2	1.84	1.95	0.55	4.34
	S3	1.58	1.65	0.55	3.78
	S7	1.71	1.35	0.55	3.61
	S8	1.39	1.05	0.75	3.19
	CS10	1.99	0.30	0.55	2.84
	CS16	2.21	0.30	0.70	3.21
	RR1	1.76	0.60	0.50	2.86
	RR2	1.78	0.30	0.55	2.63
	RR4	0.96	0.60	0.55	2.11
	RR8	1.67	0.30	0.50	2.47
	CN1	2.29	0.30	0.75	3.34
	CN11	2.31	1.50	0.70	4.51
	CN12	2.23	1.50	0.50	4.23
11.3.3	CS19	1.56	0.60	0.50	2.66
	CS21	1.56	0.60	0.70	2.86
11.3.4	CN2	1.73	1.73	0.45	3.90
	CN3	1.28	1.43	0.75	3.45
	CN4	1.33	1.43	0.65	3.41
	CN5	1.52	1.43	0.55	3.49
	CN15	1.59	2.40	0.35	4.34
	CN16	1.80	2.40	0.45	4.65
	RR3	1.41	0.90	0.55	2.86
	CS12	1.65	0.60	0.75	3.00
	CS13	1.97	0.60	0.50	3.07
	CS14	1.50	0.60	0.75	2.85
	CS17	2.14	0.60	0.50	3.24
	CS20	2.25	0.30	0.50	3.05
	GBS42	1.71	1.65	0.50	3.86
	GBS47	1.52	3.00	0.40	4.92
11.3.14	CS4	1.73	1.80	0.65	4.18
	CS9	1.33	0.00	0.50	1.83
	AE17	1.43	1.80	0.45	3.68
11.3.17	CS1	2.19	1.35	0.65	4.19
	CS3	2.10	1.35	0.60	4.05
	RR5	2.36	0.30	0.60	3.26
	RR6	2.29	0.30	0.65	3.24
	RR7	1.93	0.30	0.75	2.98
	RR9	1.84	0.30	0.55	2.69

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.18	CN6	1.97	0.30	0.30	2.57
	AE26	1.82	1.95	0.75	4.52
	AE32	1.20	0.90	0.65	2.75
	AE42	1.24	2.85	0.75	4.84
11.3.25	AE25	2.06	1.95	0.35	4.36
	AE31	1.80	1.20	0.55	3.55
	AE34	1.84	2.10	0.65	4.59
	AE44	1.69	2.85	0.55	5.09
	AE56	2.33	2.40	0.45	5.18
	AE76	2.16	1.65	0.35	4.16
11.3.27	S4	2.25	0.00	0.40	2.65
	AE04	1.89	0.75	0.50	3.14
	AE07	2.33	0.75	0.50	3.58
	AE08	2.51	0.75	0.45	3.71
	AE14	2.16	1.80	0.50	4.46
11.5.20	CS5	1.67	0.60	0.55	2.82
	CS6	1.93	2.85	0.50	5.28
	CS7	1.74	0.60	0.75	3.09
	CN7	1.91	0.30	0.45	2.66
	AE58	2.36	2.85	0.70	5.91
	AE59	1.84	2.85	0.75	5.44
	AE60	2.27	2.85	0.60	5.72

Painted Honeyeater (*Grantiella picta*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	SPP Hab Ind	Total
11.3.1	CS2	1.46	1.35	1.32	4.13
	CN10	2.44	0.90	1.32	4.66
	RR10	2.12	0.30	1.32	3.74
	RR11	1.91	0.30	1.32	3.53
	RR12	1.99	0.00	1.32	3.31
	AE06	1.67	1.35	1.32	4.34
11.3.17	CS1	2.19	1.35	1.32	4.86
	CS3	2.10	1.35	1.32	4.77
	RR5	2.36	0.30	1.32	3.98
	RR6	2.29	0.30	1.32	3.91
	RR7	1.93	0.30	1.32	3.55
	RR9	1.84	0.30	1.32	3.46
11.4.3	S6	2.06	0.60	1.72	4.38
	AE01	2.42	2.10	1.32	5.84
	AE45	2.16	0.90	1.72	4.78
	AE74	1.54	0.30	1.32	3.16
Brigalow Regrowth (11.3.17)	CS11	1.31	0.30	1.32	2.93
	CS15	1.65	0.00	1.32	2.97
	CN8	1.44	0.30	1.32	3.06
	CN9	1.95	0.00	1.32	3.27
	CN14	2.14	0.00	2.92	5.06

Regent Honeyeater (*Anthochaera phrygia*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.25	AE25	2.06	1.95	1.90	5.91
	AE31	1.80	1.20	1.90	4.90
	AE34	1.84	2.10	1.90	5.84
	AE44	1.69	2.85	1.90	6.44
	AE56	2.33	2.40	1.90	6.63
	AE76	2.16	1.65	2.40	6.21
11.3.27f	S4	2.25	0.00	1.40	3.65
11.3.27i	AE04	1.89	0.75	2.40	5.04
	AE07	2.33	0.75	2.40	5.48
	AE08	2.51	0.75	2.40	5.66
	AE14	2.16	1.80	2.40	6.36

Koala (*Phascolarctos cinereus*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.1	CS2	1.46	1.35	0.84	3.65
	CN10	2.44	0.90	0.84	4.18
	RR10	2.12	0.30	0.84	3.26
	RR11	1.91	0.30	0.84	3.05
	RR12	1.99	0.00	0.84	2.83
	AE06	1.67	1.35	0.24	3.26
11.3.2	S1	2.18	1.95	1.44	5.57
	S2	1.84	1.95	2.04	5.83
	S3	1.58	1.65	1.44	4.67
	S7	1.71	1.35	1.44	4.50
	S8	1.39	1.05	1.44	3.88
	CS10	1.99	0.30	2.04	4.33
	CS16	2.21	0.30	2.64	5.15
	RR1	1.76	0.60	2.04	4.40
	RR2	1.78	0.30	2.04	4.12
	RR4	0.96	0.60	2.64	4.20
	RR8	1.67	0.30	3.24	5.21
	CN1	2.29	0.30	1.44	4.03
	CN11	2.31	1.50	2.04	5.85
	CN12	2.23	1.50	2.04	5.77
11.3.3	CS19	1.56	0.60	1.44	3.60
	CS21	1.56	0.60	2.64	4.80
11.3.4	CN2	1.73	1.73	3.24	6.69
	CN3	1.28	1.43	2.04	4.74
	CN4	1.33	1.43	2.64	5.40
	CN5	1.52	1.43	2.04	4.98
	CN15	1.59	2.40	3.24	7.23
	CN16	1.80	2.40	2.64	6.84
	RR3	1.41	0.90	3.24	5.55
	CS12	1.65	0.60	3.24	5.49
	CS13	1.97	0.60	3.24	5.81
	CS14	1.50	0.60	3.24	5.34
	CS17	2.14	0.60	3.24	5.98
	CS20	2.25	0.30	3.24	5.79
	GBS42	1.71	1.65	2.64	6.00
	GBS47	1.52	3.00	2.64	7.16
11.3.14	CS4	1.73	1.80	3.24	6.77
	CS9	1.33	0.00	2.64	3.97
	AE17	1.43	1.80	2.04	5.27
11.3.17	CS1	2.19	1.35	1.44	4.98
	CS3	2.10	1.35	1.44	4.89
	RR5	2.36	0.30	0.84	3.50
	RR6	2.29	0.30	0.84	3.43
	RR7	1.93	0.30	0.84	3.07
	RR9	1.84	0.30	1.44	3.58

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.18	CN6	1.97	0.30	2.04	4.31
	AE26	1.82	1.95	2.64	6.41
	AE32	1.20	0.90	3.24	5.34
	AE42	1.24	2.85	1.44	5.53
11.3.25	AE25	2.06	1.95	3.24	7.25
	AE31	1.80	1.20	2.64	5.64
	AE34	1.84	2.10	2.64	6.58
	AE44	1.69	2.85	1.44	5.98
	AE56	2.33	2.40	3.24	7.97
	AE76	2.16	1.65	3.24	7.05
11.3.27	S4	2.25	0.00	3.24	5.49
	AE04	1.89	0.75	2.64	5.28
	AE07	2.33	0.75	2.64	5.72
	AE08	2.51	0.75	3.24	6.50
	AE14	2.16	1.80	3.24	7.20
11.4.3	S6	2.06	0.60	0.12	2.78
	AE01	2.42	2.10	0.72	5.24
	AE45	2.16	0.90	0.12	3.18
	AE74	1.54	0.30	0.12	1.96
11.5.1	CN13	2.46	1.35	2.52	6.33
	AE20	1.85	2.85	1.92	6.62
	AE24	1.67	1.95	1.92	5.54
	AE46	1.78	2.85	1.32	5.95
	AE73	2.01	2.10	1.32	5.43
11.5.1 (regrowth)	AE19	1.14	0.90	0.72	2.76
	AE49	0.98	1.20	0.72	2.90
11.5.4	AE02	1.91	0.90	0.72	3.53
	AE03	2.19	2.10	1.32	5.61
	AE10	1.91	1.05	1.92	4.88
	AE11	2.25	1.05	1.92	5.22
	AE12	2.33	2.10	1.32	5.75
	AE55	1.89	0.90	1.32	4.11
11.5.20	CS5	1.67	0.60	1.32	3.59
	CS6	1.93	2.85	0.72	5.50
	CS7	1.74	0.60	0.72	3.06
	CN7	1.91	0.30	0.72	2.93
	AE58	2.36	2.85	0.72	5.93
	AE59	1.84	2.85	0.72	5.41
	AE60	2.27	2.85	0.72	5.84

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.7.4	CS8	2.01	0.00	1.32	3.33
	AE22	2.27	2.85	1.32	6.44
	AE41	1.95	2.85	1.32	6.12
	AE47	1.88	2.85	1.32	6.05
	AE 50	2.01	2.85	0.72	5.58
	AE66	2.06	2.70	1.32	6.08
	AE70	2.10	2.10	2.52	6.72
	GBS1	2.87	2.85	1.32	7.04
11.7.6	AE28	2.04	2.40	0.72	5.16
	AE36	1.65	1.20	0.72	3.57
	EPB47	1.84	3.00	0.72	5.56
	EPB51	1.91	3.00	0.72	5.63
	EPB58	1.73	3.00	0.72	5.45
11.7.6 (regrowth)	CS18	1.93	1.05	0.72	3.70
Brigalow regrowth (11.3.17)	CS11	1.31	0.30	0.12	1.73
	CS15	1.65	0.00	0.72	2.37
	CN8	1.44	0.30	0.12	1.86
	CN9	1.95	0.00	0.72	2.67
Brigalow regrowth (11.4.3)	CN14	2.14	0.00	0.72	2.86

Greater Glider (*Petauroides volans*) HQS – Site Summary Data

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.4	CN2	1.73	1.73	0.52	3.97
	CN3	1.28	1.43	0.52	3.22
	CN4	1.33	1.43	0.32	3.08
	CN5	1.52	1.43	0.32	3.26
	CN15	1.59	2.40	1.32	5.31
	CN16	1.80	2.40	1.32	5.52
	RR3	1.41	0.90	1.52	3.83
	CS12	1.65	0.60	0.32	2.57
	CS13	1.97	0.60	0.32	2.89
	CS14	1.50	0.60	0.92	3.02
	CS17	2.14	0.60	1.12	3.86
	CS20	2.25	0.30	0.52	3.07
	GBS42	1.71	1.65	1.12	4.48
	GBS47	1.52	3.00	1.52	6.04
11.3.25	AE25	2.06	1.95	2.12	6.13
	AE31	1.80	1.20	0.92	3.92
	AE34	1.84	2.10	1.12	5.06
	AE44	1.69	2.85	1.52	6.06
	AE56	2.33	2.40	2.12	6.85
	AE76	2.16	1.65	2.72	6.53
11.3.27f	S4	2.25	0.00	0.52	2.77
11.3.27f	AE04	1.89	0.75	1.72	4.36
	AE07	2.33	0.75	1.52	4.60
	AE08	2.51	0.75	1.32	4.58
	AE14	2.16	1.80	1.32	5.28
11.7.6	AE28	2.04	2.40	0.52	4.96
	AE36	1.65	1.20	0.72	3.57
	EPB47	1.84	3.00	0.32	5.16
	EPB51	1.91	3.00	0.72	5.63
	EPB58	1.73	3.00	0.52	5.25
11.7.7	N3	2.27	2.10	1.12	5.49
	AE21	1.97	1.95	0.52	4.44
	AE38	2.38	2.70	0.92	6.00
	AE62	2.23	2.40	0.92	5.55
	AE69	2.36	2.70	1.72	6.78

Southern Long-eared Bat (*Nyctophilus corbeni*) HQS – Site Summary Data

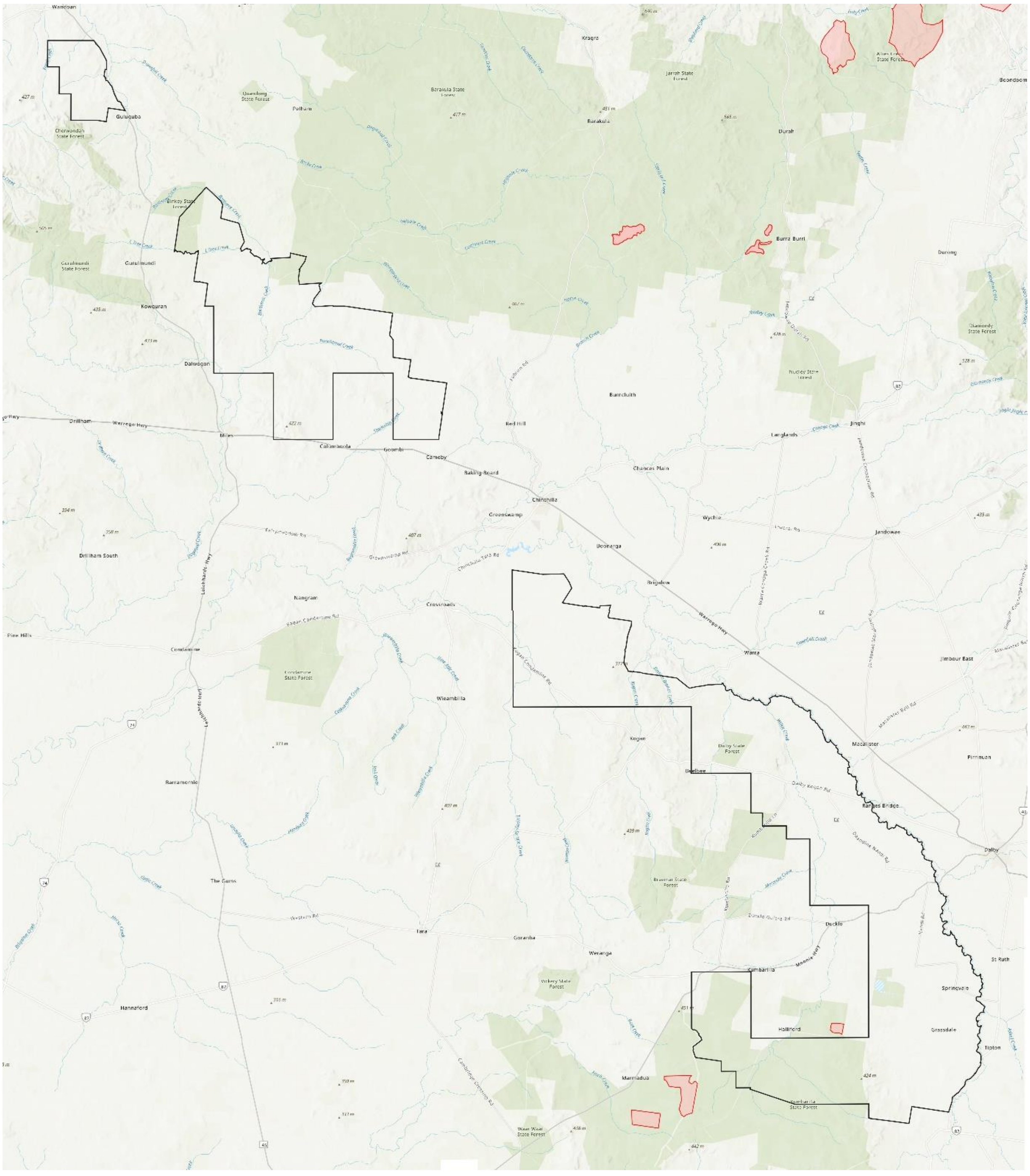
Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.3.14	CS4	1.73	1.80	0.60	4.13
	CS9	1.33	0.00	0.20	1.53
	AE17	1.43	1.80	1.60	4.83
11.3.18	CN6	1.97	0.30	0.20	2.47
	AE26	1.82	1.95	0.60	4.37
	AE32	1.20	0.90	0.20	2.30
	AE42	1.24	2.85	1.80	5.89
11..5.1	CN13	2.46	1.35	1.40	5.21
	AE20	1.85	2.85	1.60	6.30
	AE24	1.67	1.95	1.40	5.02
	AE46	1.78	2.85	2.00	6.63
	AE73	2.01	2.10	0.20	4.31
11.5.4	AE02	1.91	0.90	0.40	3.21
	AE03	2.19	2.10	0.20	4.49
	AE10	1.91	1.05	0.40	3.36
	AE11	2.25	1.05	0.20	3.50
	AE12	2.33	2.10	0.20	4.63
	AE55	1.89	0.90	0.60	3.39
11.5.20	CS5	1.67	0.60	0.20	2.47
	CS6	1.93	2.85	0.60	5.38
	CS7	1.74	0.60	0.20	2.54
	CN7	1.91	0.30	0.20	2.41
	AE58	2.36	2.85	1.60	6.81
	AE59	1.84	2.85	1.40	6.09
	AE60	2.27	2.85	0.60	5.72
11.5.21	GBS15	1.78	2.70	1.60	6.08
11.7.4	CS8	2.01	0.00	1.60	3.61
	AE22	2.27	2.85	0.80	5.92
	AE41	1.95	2.85	1.40	6.20
	AE47	1.88	2.85	1.40	6.13
	AE 50	2.01	2.85	1.20	6.06
	AE66	2.06	2.70	1.00	5.76
	AE70	2.10	2.10	1.60	5.80
	GBS1	2.87	2.85	1.80	7.52
11.7.6	AE28	2.04	2.40	1.20	5.64
	AE36	1.65	1.20	0.20	3.05
	EPB47	1.84	3.00	0.80	5.64
	EPB51	1.91	3.00	1.20	6.11
	EPB58	1.73	3.00	0.80	5.53

Regional Ecosystem	Site	Condition	Context	Spp Hab Ind	Total
11.7.7	N3	2.27	2.10	1.00	5.37
	AE21	1.97	1.95	1.60	5.52
	AE38	2.38	2.70	2.20	7.28
	AE62	2.23	2.40	1.00	5.63
	AE69	2.36	2.70	1.20	6.26

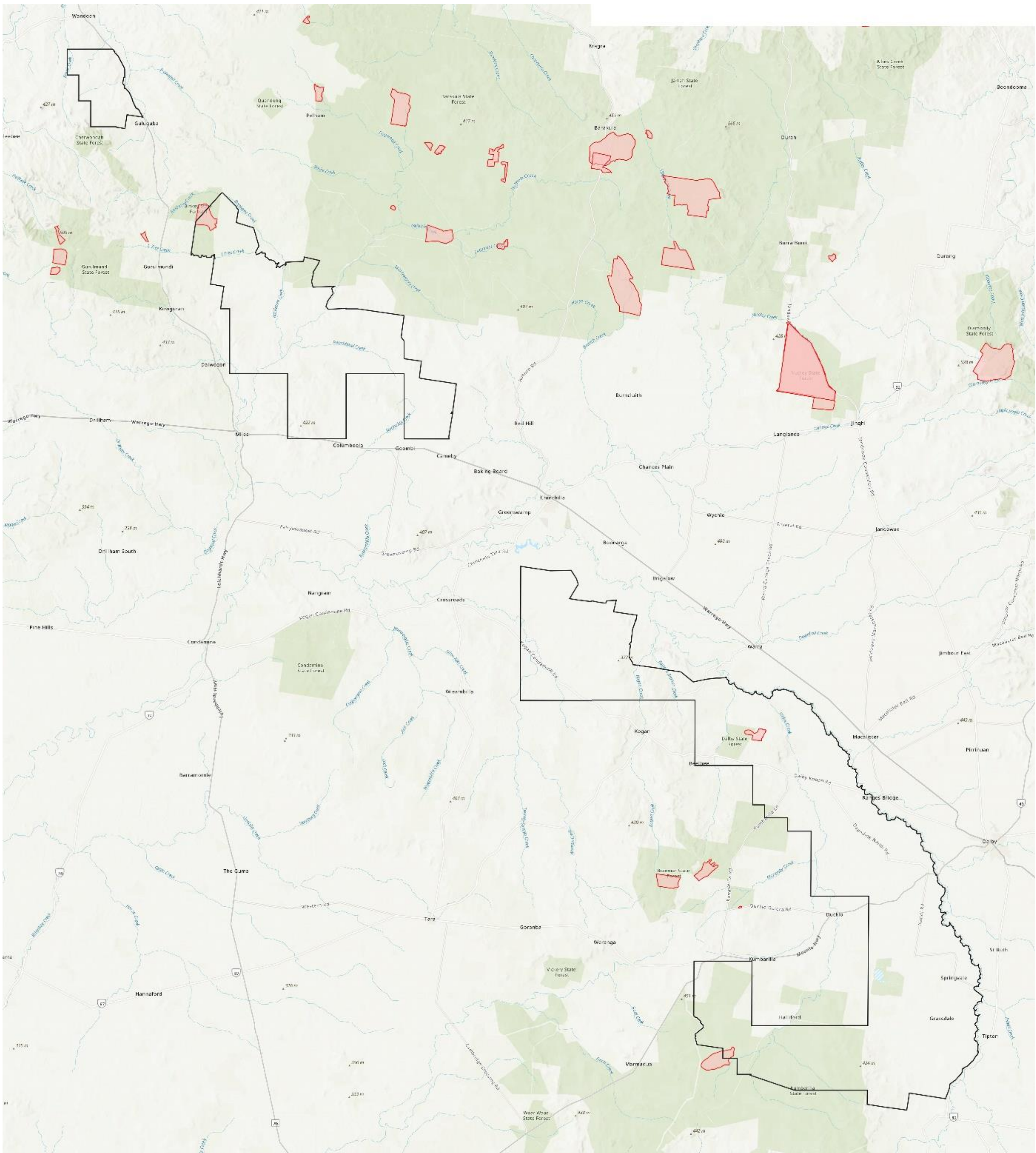
Appendix C: Historic Wildfire Maps

The following wildfire maps are based on 'Queensland Parks Fire History' data (Department of Environment and Science 2020, available from: https://www.arcgis.com/home/item.html?id=a0c6ac4bfb32471ba576bc2db0814abe). The dataset illustrates planned burns (not indicated on maps provide here) and wildfire which occurs within or affects Queensland protected estate. It does not represent a complete overview of fire history.

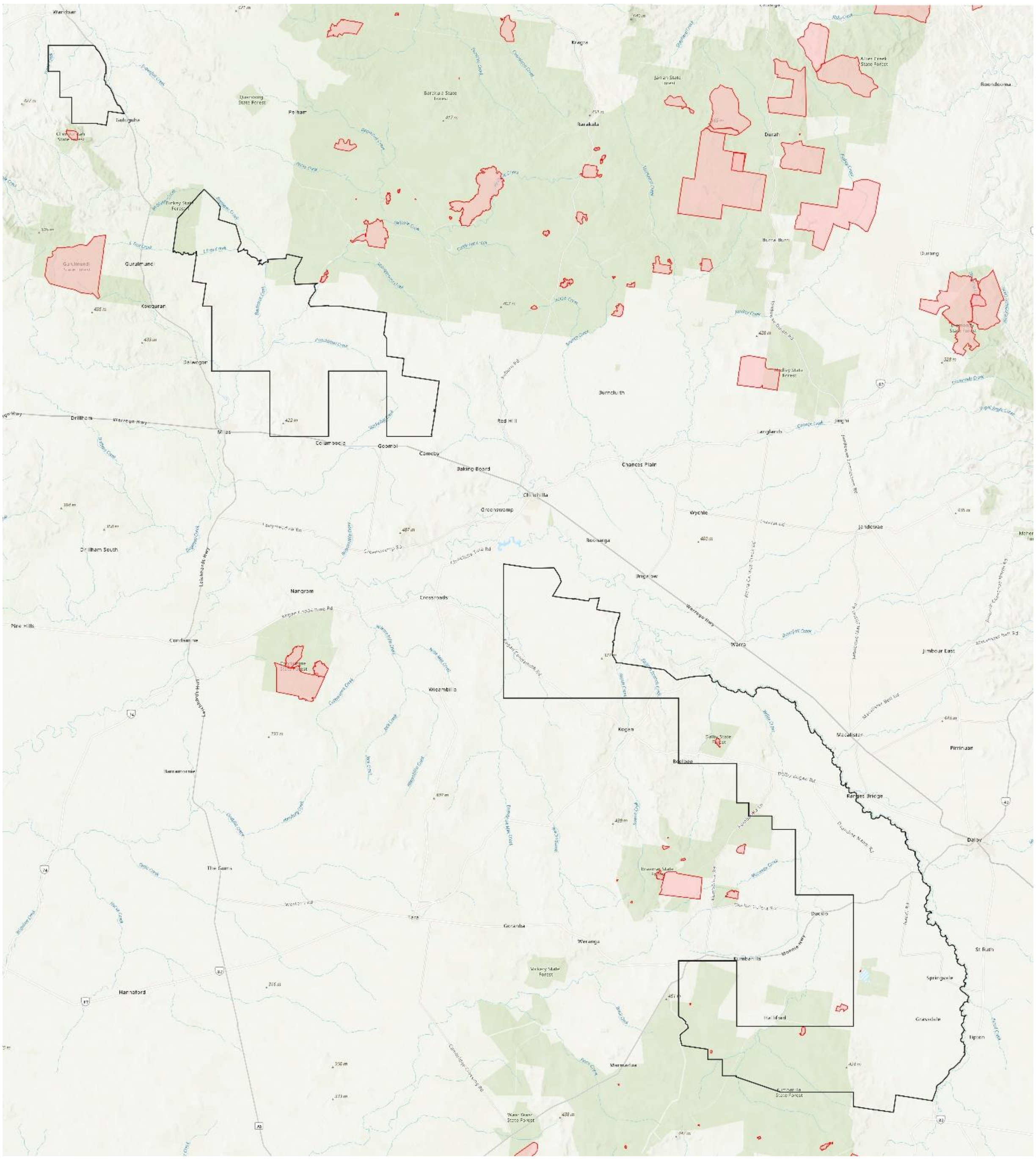
<u>1980-1990</u>



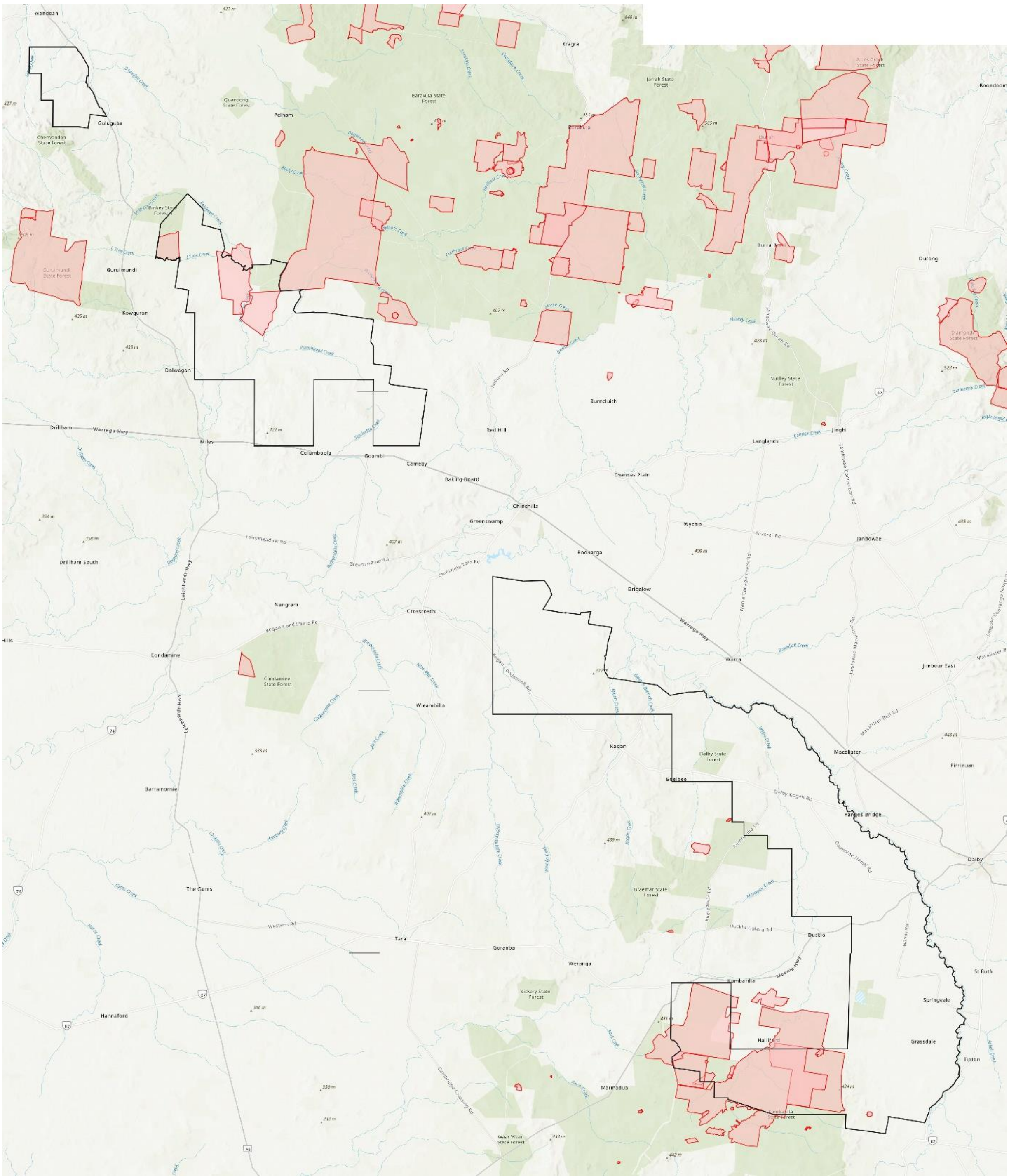
1991-2000



2001-2010



2011+


Chinchilla
Miles
Dalby
Kogan
Condamine
Columboola
Brigalow
Warra
Macalister
Jandowae
Tara
Meandarra