



Nest box Monitoring Report - Woolgoolga to Ballina
Pacific Highway Upgrade (Sections 3 - 11) Year 3, 2021

Pacific Complete

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Abbreviations

Abbreviation	Description
BC Act	NSW <i>Biodiversity Conservation Act 2016</i>
ELA	Eco Logical Australia
EPA	Environmental Protection Authority
HBT	Hollow-bearing tree
HDF	Hollow dependent fauna
MCoA	Ministers Condition of Approval
NBMP	Nest Box Management Plan
NBRZ	Nest Box Replacement Zone
NP	National Park
NR	Nature Reserve
PC	Pacific Complete
SCA	State Conservation Area
TfNSW	Transport for New South Wales
W2B	Woolgoolga to Ballina

Executive Summary

Eco Logical Australia (ELA) has been engaged by Transport for NSW (TfNSW) to undertake Nest Box Installation and Monitoring for Sections 3 - 11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B). This includes supply, delivery, installation, monitoring and maintenance of approximately 873 nest boxes (including 26 Hollowhog) of 22 different types along the 155 km Pacific Highway corridor between Woolgoolga and Ballina. Nest box installation is one of many mitigation measures being implemented to minimise impacts to native fauna species from the W2B project and forms part of the Minister's Conditions of Approval for the project. Nest boxes are monitored by ELA twice per year in Autumn and Spring in 2018, 2019, 2021 with additional monitoring planned in 2023. This report details the results of the third year of monitoring undertaken in 2021. This year a total of 240 nest boxes and 26 Hollowhog were installed (total of 266). This number consists of:

- 204 nestboxes that were required to meet the 100% nest box quota.
- 36 nest boxes and 26 Hollowhogs (total of 62) to replace the 55 non-functional or missing boxes identified in the 2019-20 report.

Therefore an additional 7 nest boxes were installed in Spring 2021.

Eighteen vertebrate species were recorded in nest boxes during 2019-21 with four mammals accounting for the majority of records. These were *Trichosurus vulpecula* (Common Brushtail Possum), *Chalinolobus gouldii* (Gould's Wattleed Bat), *Nyctophilus bifax* (Eastern Long-eared Bat) and *Petaurus norfolcensis* (Squirrel Glider). The Eastern Long-eared Bat and Squirrel Glider are listed as vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act).

Performance targets have been assigned for the project to guide nest box management and maintenance. These criteria have been derived from review of the available literature on rates of occupancy for nest boxes on similar TfNSW Pacific Highway upgrade projects. Performance targets for the nest box monitoring include:

- > 50% of boxes showing evidence of use by native fauna
- ≥ 5% or more of the nest boxes being occupied by species or fauna group for which the box was designed
- Pest species occupying less than 15 % of boxes
- < 10% of boxes requiring repair and maintenance

The results of nest box monitoring in 2021 found that performance targets 3 and 4 were achieved, but performance targets 1 and 2 (box usage by native fauna and target species occupancy) were less than the desired target. Widespread and severe bushfires over spring and summer 2019-20 may have contributed to this lower than expected usage of boxes by native fauna. The short time period between installation of 240 boxes and the spring 2021 monitoring may also have contributed to this lower than expected usage of boxes by native fauna. The lack of use of nest boxes by target species or species groups is also a feature common to other RMS nest box projects (Goldingay 2019) and is not unexpected.

There were 81 boxes identified that required maintenance or repair / replacement during 2021. Of those, 51 need to be replaced because they were either destroyed by fire, termites, tree fall or persistently occupied by European bees. The remaining 30 nestboxes require maintenance, 14 boxes

had been inhabited by termites wasps and bees and were left with the lid propped open between monitoring events to encourage pest species to vacate the box.

A comparison was conducted between boxes constructed of timber and CYPLAS (a mixture of Queensland Cypress pine and recycled plastic). A large proportion (70%) of the native vertebrate species recorded inside boxes over the current and previous monitoring events have utilised CYPLAS boxes.

The occupancy rates of native fauna in timber vs CYPLAS boxes was similar in Autumn 2021. However occupancy of boxes by native fauna dropped in spring 21 for both material types with a larger reduction in occupancy for CYPLAS boxes. A similar trend was also detected in 2019.

There was evidence of breeding recorded in both timber and CYPLAS nest boxes. Three species were recorded breeding in timber boxes during 2021: Common Brushtail Possum, Sugar Glider and the threatened Squirrel Glider. There was evidence of birds previously nesting within timber and CYPLAS boxes, indicated by the presence of eggshells on a number of occasions.

In terms of pest species uptake, CYPLAS boxes performed much better than timber boxes, largely due to termites not destroying CYPLAS boxes and greatly reduced rates of use by ants, bees and invertebrates. Repair and maintenance requirements for CYPLAS boxes were lower than for timber boxes.

1. Introduction

1.1 Background

Eco Logical Australia (ELA) has been engaged by Transport for New South Wales (TfNSW) to undertake nest box installation and monitoring for Sections 3 – 11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B), as per the specifications set out in the Nest Box Management Plans (NBMPs) for each Section (GeoLINK 2014a and 2014b, AECOM 2014, Biosis 2014, Melaleuca Group 2014, Australian Museum Consulting 2014). This includes the supply, delivery, installation, monitoring and maintenance of approximately 873 nest boxes (including 26 Hollowhog) along the Pacific Highway corridor between Woolgoolga and Ballina. However, this number fluctuates due to maintenance, repairs, and external factors such as weather events. Currently 847 nest boxes are installed, as well as 26 Hollowhog according to ELA's dataset. The W2B project comprises approximately 155 km of upgraded highway achieving a four-lane divided road extending north of Woolgoolga to south of Ballina. The W2B project has been sub-divided into sections from 1 to 11, with Sections 1 and 2 having already been completed. Sections 3 – 11 of the W2B project (the subject site) runs from Glenugie to Ballina, passing through largely cleared floodplains and crossing the Clarence and Richmond Rivers, and passing through or along the edges of forested lands including Glenugie, Mororo, Devil's Pulpit, Tabbimoble and Doubleduke State Forests, Yaegl and Tabbimoble Nature Reserves (NR), Yuraygir, Bundjalung and Broadwater National Parks (NP) and Bundjalung State Conservation Area (SCA).

The primary objective of the NBMP for each Section is to outline measures to mitigate the impacts of vegetation clearing on hollow-dependent fauna. In doing so, the NBMPs provide guidance on the provision of nest boxes as a short-term compensatory mechanism for fauna that may be displaced by the loss of habitat trees within the clearing area, inclusive of denning, roosting and nesting resources. The list of threatened hollow-dependent species (referred to as target species) in each NBMP is slightly different for each Section, because of changes in vegetation and proximity of each Section to existing populations of threatened species. Table 1 provides a combined list of 24 threatened hollow-dependent fauna (HDF) species known from records within 5 km of the W2B alignment that were targeted by the NBMPs and / or listed as threatened under the NSW *Biodiversity Conservation Act 2016* (BC Act) and/or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) since the NBMPs were prepared.

The NBMPs provide details on the numbers and types of nest boxes required to be installed, based upon the results of ground based surveys of HBTs within the clearing footprint, and in reference sites adjacent to the alignment. Surveys of HBTs estimated the number and size class of hollows contained within each HBT scheduled to be cleared, and this list of hollows was used to provide the proportional allocation of nest box types within each section. The Nest Box Replacement Zones (NBRZs) are smaller areas within each W2B section, that provide a practical organisational structure and suitable location for the installation of nest boxes. Nest boxes are required to be installed in NBRZs where the density of HBTs in the adjacent landscape is equal to, or less than, four HBTs per hectare. There were no surveys of HBTs for resident fauna completed within the NBRZs.

The Nest Box Management Plans for the project state that nest boxes are to be monitored twice per year in 2018, 2019, 2021 and 2023. The NBMPs indicate that nest boxes are to be monitored in Winter and Spring when fauna are most active, and most likely to be using nest boxes. Timing of monitoring

events was adjusted (prior to commencement of monitoring) to Autumn and Spring to align with timing of nest box monitoring in Sections 1 and 2 of the W2B highway upgrade. This is per the agreement with the Environmental Protection Authority (EPA) and was approved by the Environmental Representative for W2B.

This 2021 report outlines details relating to the installation of nest boxes, the standard inspection methods used, and the results of inspections conducted in Autumn and Spring 2021.

The report also outlines whether the nest boxes are meeting performance indicator targets and provides a range of corrective actions to determine the most appropriate measures to achieve the performance criteria.

When discussing nest box monitoring results the following definitions apply:

- Occupancy: a nest box is inhabited by an animal during the visual inspection
- Evidence of use: a box contains signs that an animal has visited and used the nest box for shelter or breeding purposes. Signs of visitation by an animal include nests of various forms, scats / guano, feathers, shed skins, bones, eggs, eggshells, scratches on the sides of the nest box, chewing around the entrance hole, a depression in the sawdust provided as bedding material, hair or fur.
- Usage: Occupancy and evidence of use combined

Table 1: Combined list of threatened hollow-dependent fauna species and the target nest box type included in the NBMPs for Sections 3 – 11 of the W2B project.

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
Aves				
<i>Calyptorhynchus lathami</i>	Glossy Black-cockatoo	V		Cockatoo/Large Owl
<i>Climacteris picumnus</i>	Brown Treecreeper	V		Tree Creeper
<i>Glossopsitta pusilla</i>	Little Lorikeet	V		Small Parrot
<i>Ninox connivens</i>	Barking Owl	V		Cockatoo/Large Owl
<i>Ninox strenua</i>	Powerful Owl	V		Cockatoo/Large Owl
<i>Tyto novaehollandiae</i>	Masked Owl	V		Cockatoo/Large Owl
<i>Tyto tenebricosa</i>	Sooty Owl	V		Cockatoo/Large Owl
Mammals				
<i>Dasyurus maculatus</i>	Spotted-tailed Quoll	V	E	Spotted-tailed Quoll
<i>Petauroides volans</i>	Greater Glider		V	Possum/Large-Glider
<i>Petaurus australis</i>	Yellow-bellied Glider	V		Possum/Large-Glider
<i>Petaurus norfolcensis</i>	Squirrel Glider	V		Glider (front-entry, rear-entry)
<i>Phascogale tapoatafa</i>	Brush-tailed Phascogale	V		Phascogale
Microbats				
<i>Chalinolobus dwyeri</i>	Large-eared Pied Bat	V	V	Single, 2, 3 or 4-chambered microbat

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
<i>Chalinolobus nigrogriseus</i>	Hoary Wattled Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Falsistrellus tasmaniensis</i>	Eastern False Pipistrelle	V		Single, 2, 3 or 4-chambered microbat
<i>Kerivoula papuensis</i>	Golden-tipped Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Miniopterus australis</i>	Little Bent-winged Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Miniopterus schreibersii oceanensis</i>	Eastern Bent-winged Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Mormopterus beccarii</i>	Beccari's Free-tailed Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Mormopterus norfolkensis</i>	Eastern Free-tailed Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Myotis macropus</i>	Southern Myotis	V		Single, 2, 3 or 4-chambered microbat
<i>Nyctophilus bifax</i>	Eastern Long-eared Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tailed Bat	V		Single, 2, 3 or 4-chambered microbat
<i>Scoteanax rueppellii</i>	Greater Broad-nosed Bat	V		Single, 2, 3 or 4-chambered microbat

1.2 Performance criteria

The monitoring program is intended to allow for evaluation of the nest box strategy and the effectiveness of nest boxes, as alternative and replacement habitat for the loss of hollows. It will also allow for repair and replacement of nest boxes over time, to ensure that alternative habitat remains viable in the medium term. Evaluation of the nest box strategy over the monitoring period is made by using the following performance criteria:

- 1. Use of nest boxes by a wide range of native fauna.** If the combined species overall rates of use of nest boxes are equal to or greater than 50%, the performance measure is considered to have been achieved.
- 2. Use of nest boxes designed for a target species being used by that species.** Measured by reporting on the percentage of boxes occupied by the target species or species group (nest box type). If the rate of occupation is equal to or greater than 5%, the performance measure is considered to have been achieved.
- 3. Low rates of usage by exotic fauna.** Measured by reporting on the percentage of boxes occupied by pest species. If the percentage is equal to or less than 15%, the performance measure is considered to have been achieved. If exotic fauna occupation is higher than 15%, consider applying suitable deterrents and/or re-positioning nest box to deter pest species.

- 4. Reduced maintenance requirements.** Measured by reporting on the percentage of boxes requiring maintenance or repair. If the percentage is less than 10%, the performance measure is considered to have been achieved.

It should be noted that the NBMPs did not provide measurable targets for the performance indicators. The percentage targets being used in this series of monitoring reports are derived from review of the scientific literature on rates of occupancy for nest boxes on similar TfNSW Pacific Highway upgrade projects (Ecosure 2017, Goldingay 2019, Lindenmayer et. Al. 2017, Sandpiper 2013, 2015, 2016a, 2016b, 2016c, 2017a and 2017b) and on threatened species research programs where nest boxes were installed and monitored (Connecting Country 2016). The reviewed literature is largely focused upon box usage by arboreal mammal species as this fauna group is the most commonly studied in conjunction with nest boxes.

It is also important to note that many of the 24 target threatened fauna species (Table 1) have not been recorded using nest boxes.

1.3 Installation

Nest boxes were installed by a number of contractors over a number of separate periods of installation between 2015 and 2021, with the majority installed in 2016 and 2017. As a result, boxes have been in place for between six months and 5.5 years as of December 2021. Dates of installation for each section appear in Table 2 below (where date of installation was available or provided by contractors). Locations of NBRZs containing nest boxes in the subject site are shown in Figure 1-9 below.

Nest boxes were constructed from a range of materials including locally sourced hardwood, marine ply and CYPLAS (recycled plastic and cypress pine). Using range of materials aims to provide data on the nest box preferences of fauna in the region, and the performance of different nest box materials (Photo 1-Photo 3). Approximately two thirds of boxes (482 in the 70% pre-vegetation clearance allocation) were to be constructed from timber because boxes made of this material are known to have previously been used by a wide range fauna species. Approximately one third of boxes (180 in the pre-vegetation clearance 70% allocation) were to be constructed from CYPLAS. The reason for the lower proportional allocation of CYPLAS boxes was because this material had not been documented to perform at levels similar to timber boxes. Nest boxes were purchased from a range of suppliers including commercial businesses, Grafton Men's Shed and Orara & Clarence Industries, Caringa, which provides supported employment to people with disabilities. A total of 20 types of nest boxes were installed within Sections 3 – 11 of the W2B project and the entrance size of each nest box type is listed in Table 3 below.

Nest boxes on the W2B project are installed at heights ranging from 3 to 18 m, in line with the installation guidelines for each species as set out within the NBMPs. All NBRZs were inspected prior to installation of boxes to ensure each receptor site contained suitable habitat for nest box installation and would remain accessible throughout the construction and operational periods of the W2B project. There is no data currently available on the density of HBTs within each NBRZ.

Table 2: Timing of nest box installations by year on Sections 3 – 11 of the W2B Pacific Highway upgrade.

Section	2015	2016	2017	2018	2019	2021
3A	-	-	-	January	-	November
3	-	February, July, September	March, June	-	-	November
4	June, September	February, June	-	-	-	November
5	-	February, October	-	-	-	November
6	-	December	January, July	October	-	November
7	-	July, November	January	-	-	November
8	September	July, November	January	-	-	November
9	-	-	January	-	-	November
10	-	November	May	-	-	November
11	October	November	May	-	-	November

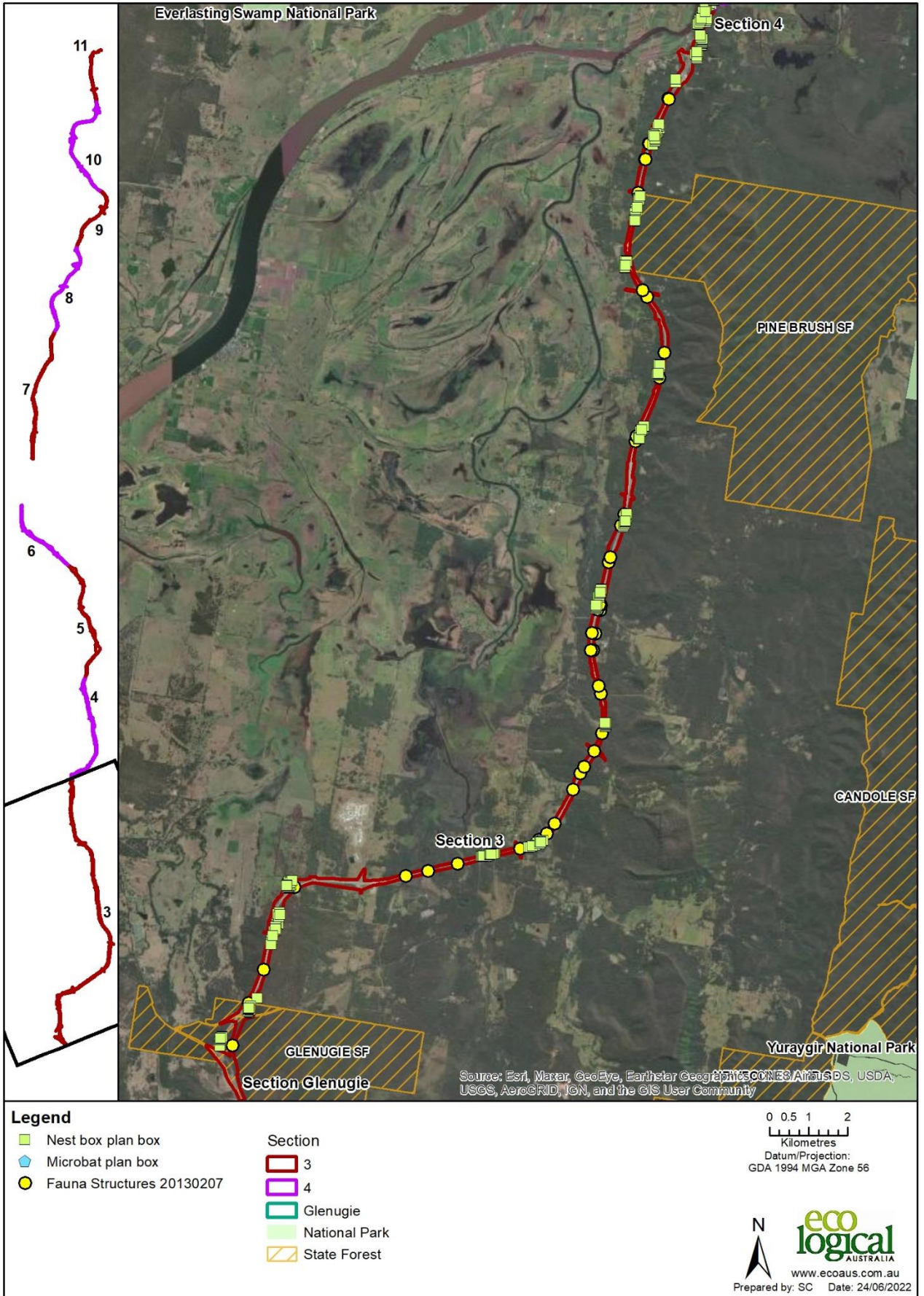


Figure 1: Section 3 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

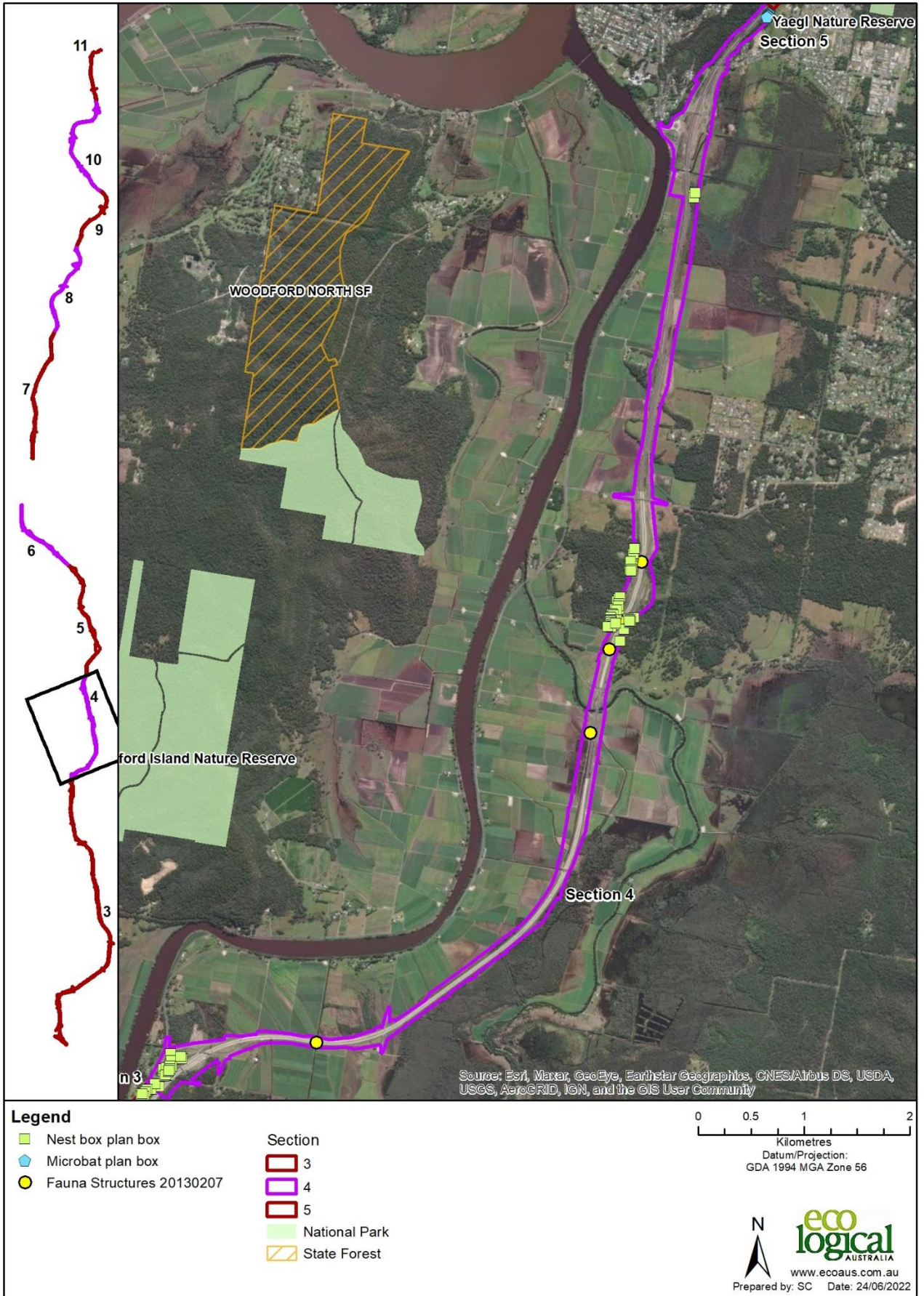


Figure 2: Section 4 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

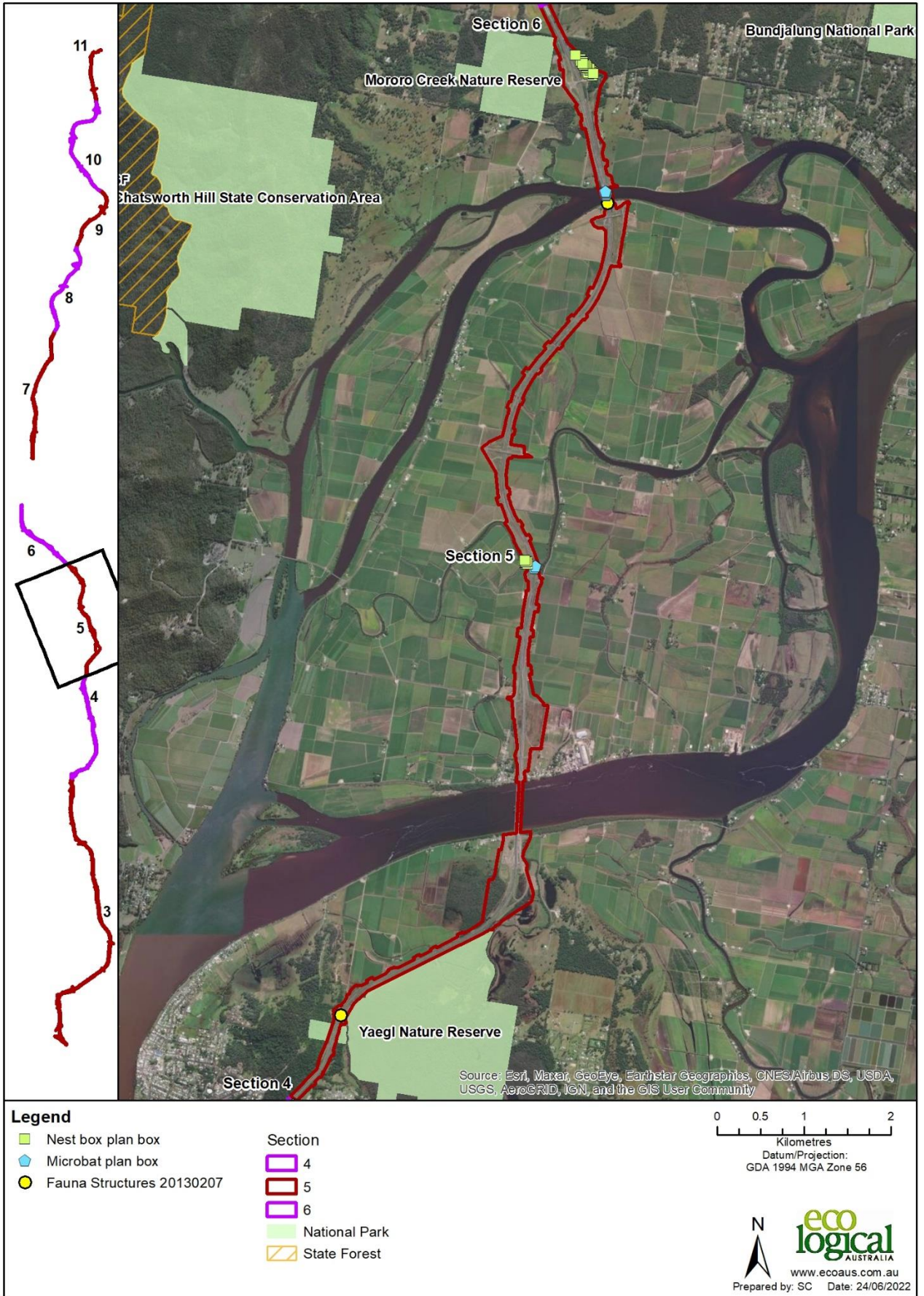


Figure 3: Section 5 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

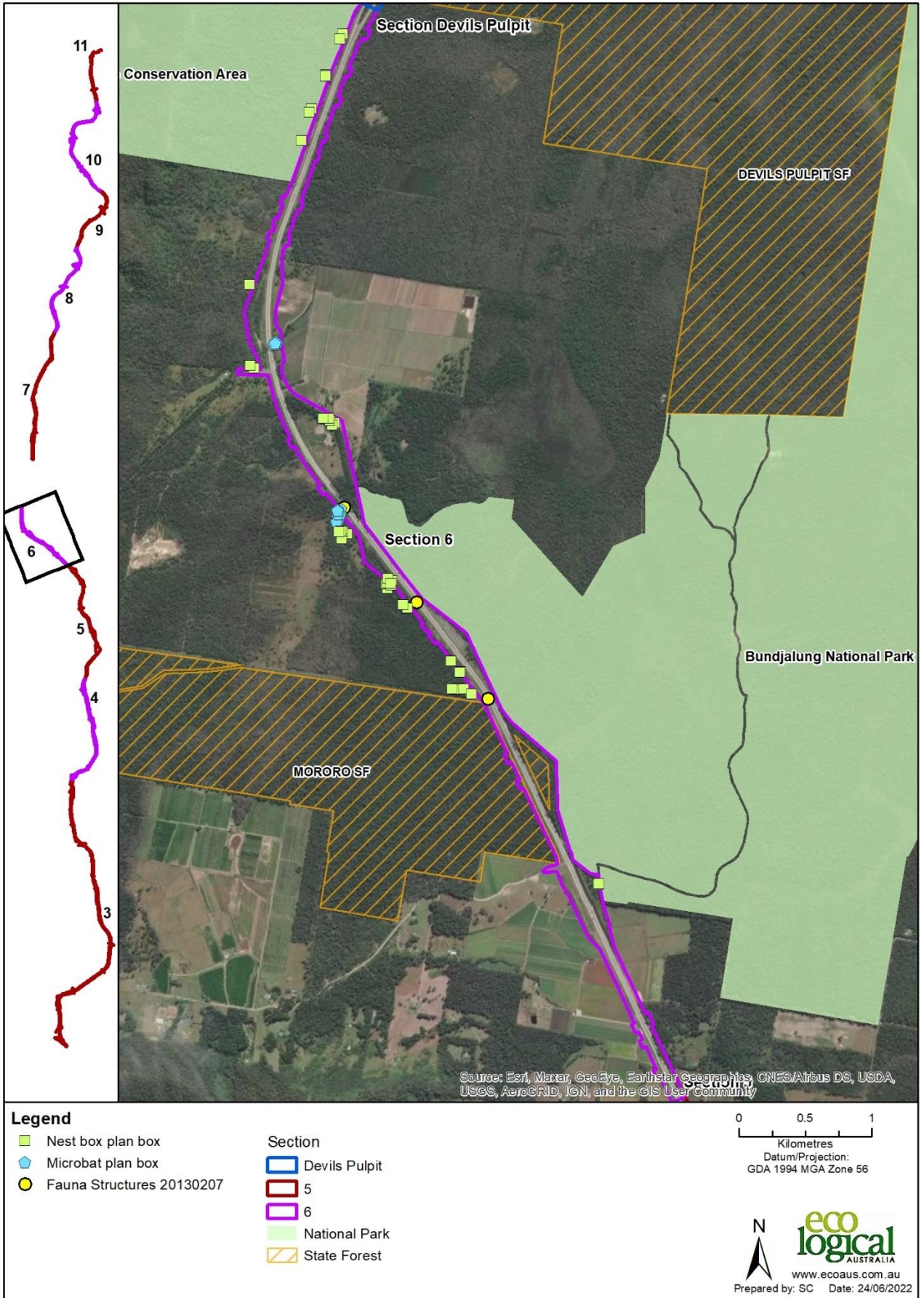


Figure 4: Section 6 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

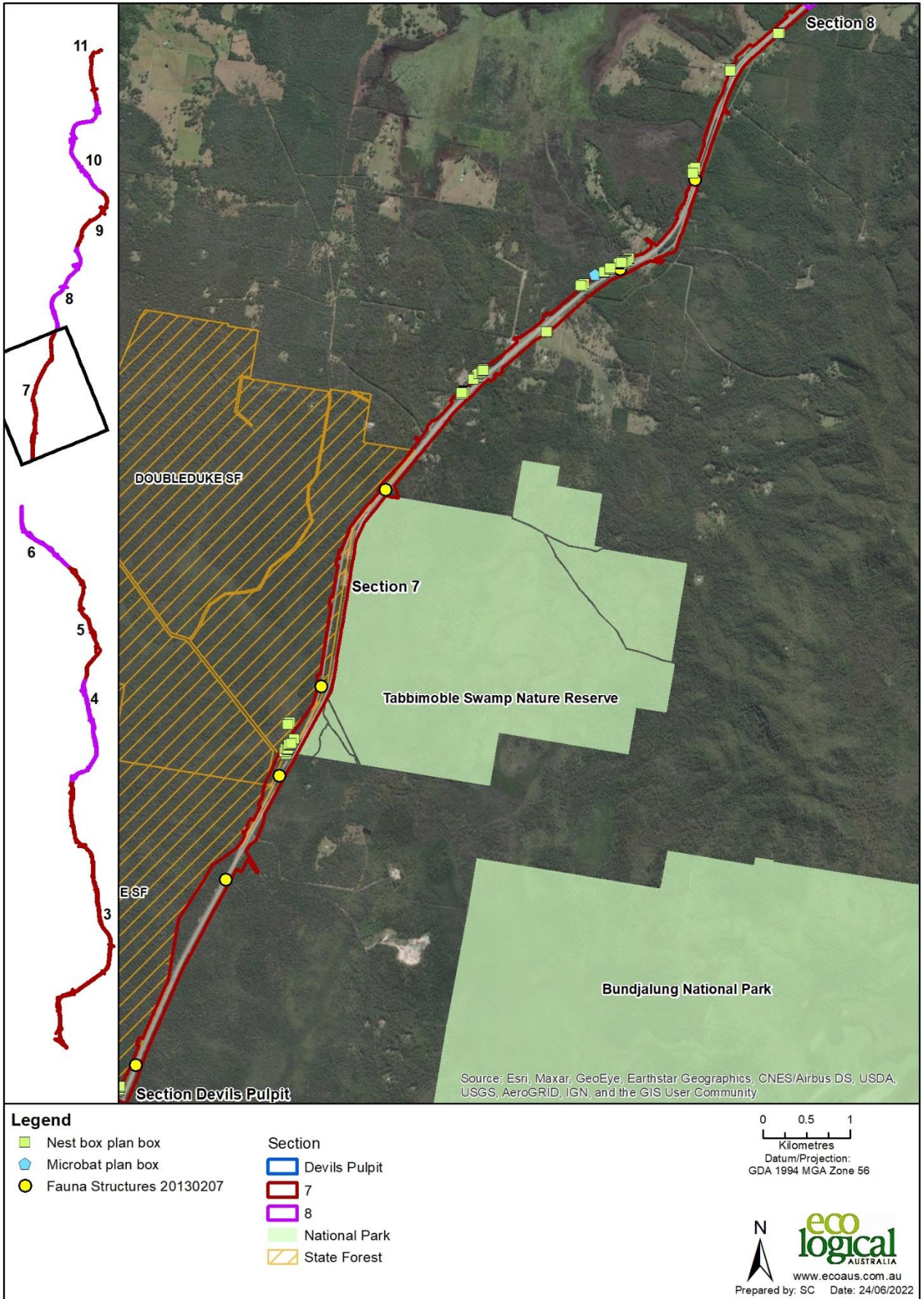


Figure 5: Section 7 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

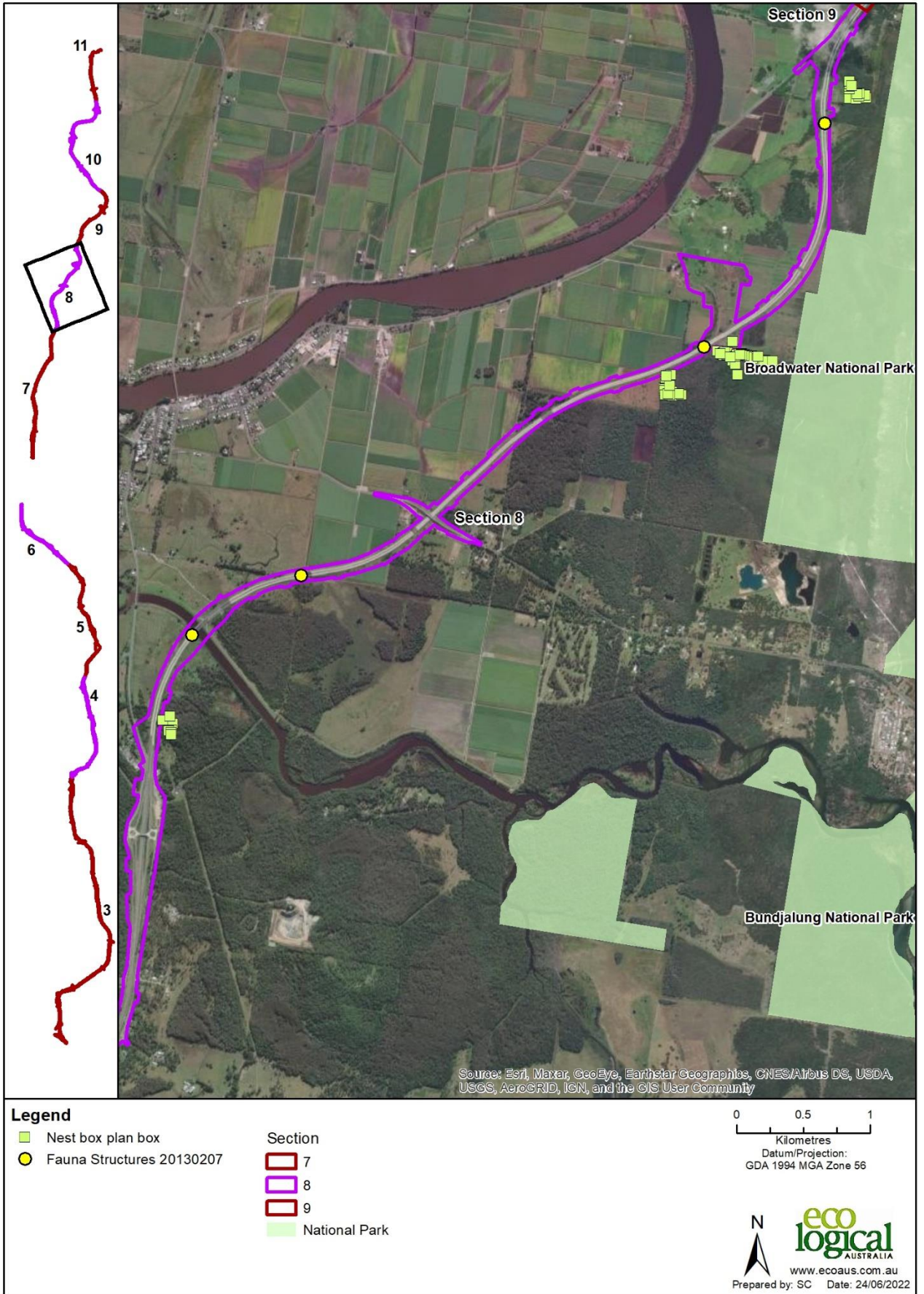


Figure 6: Section 8 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

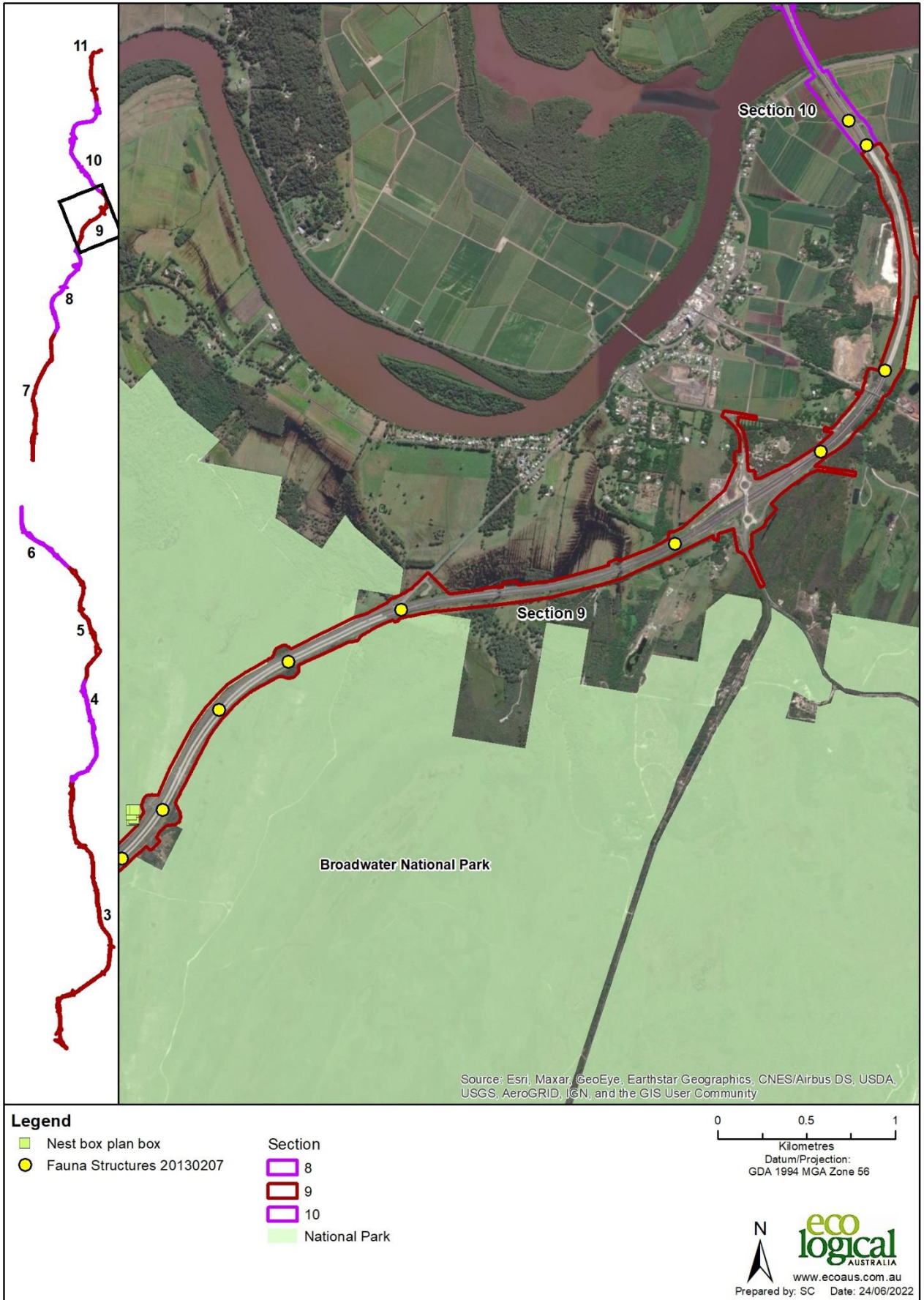


Figure 7: Section 9 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

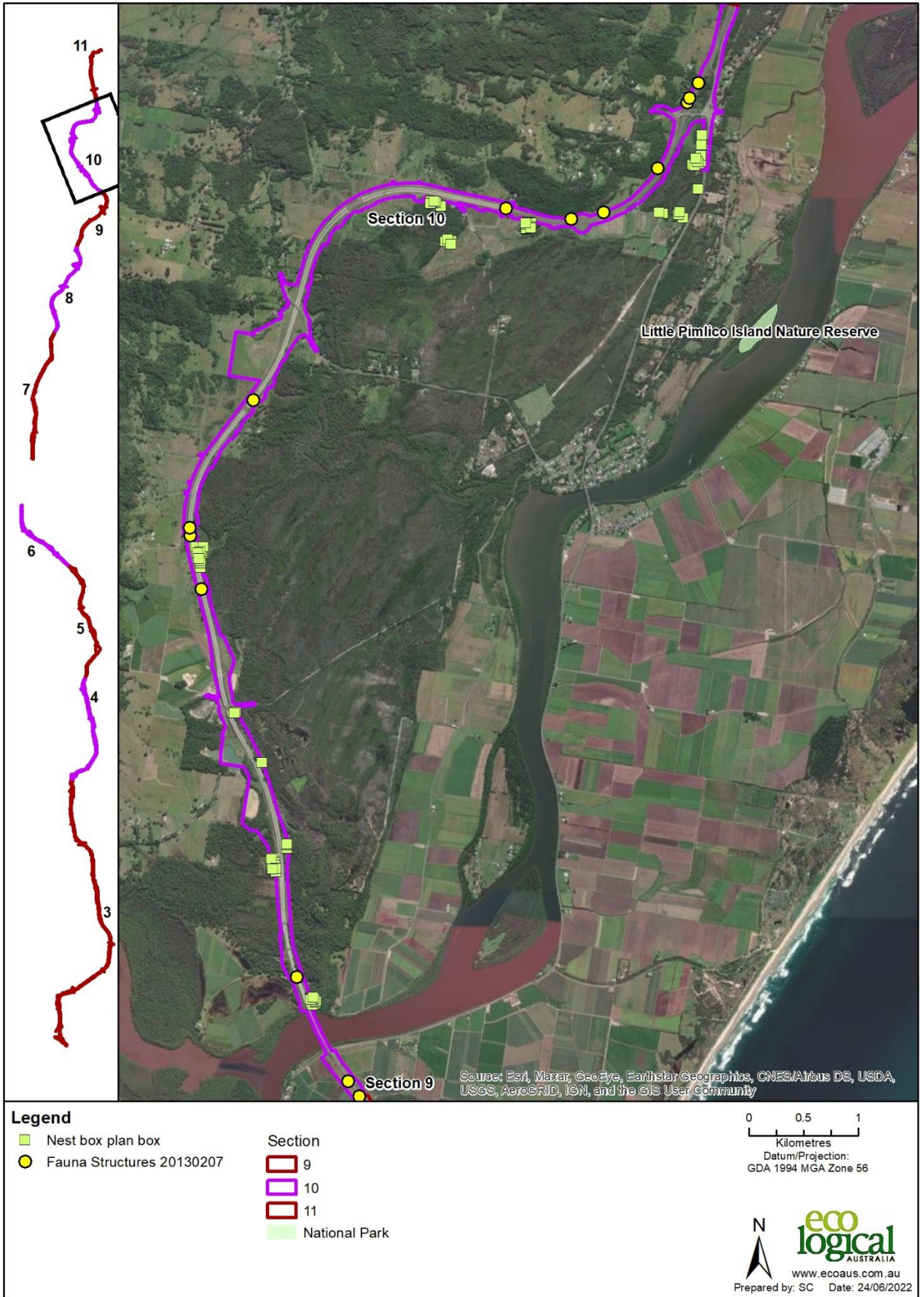


Figure 8: Section 10 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

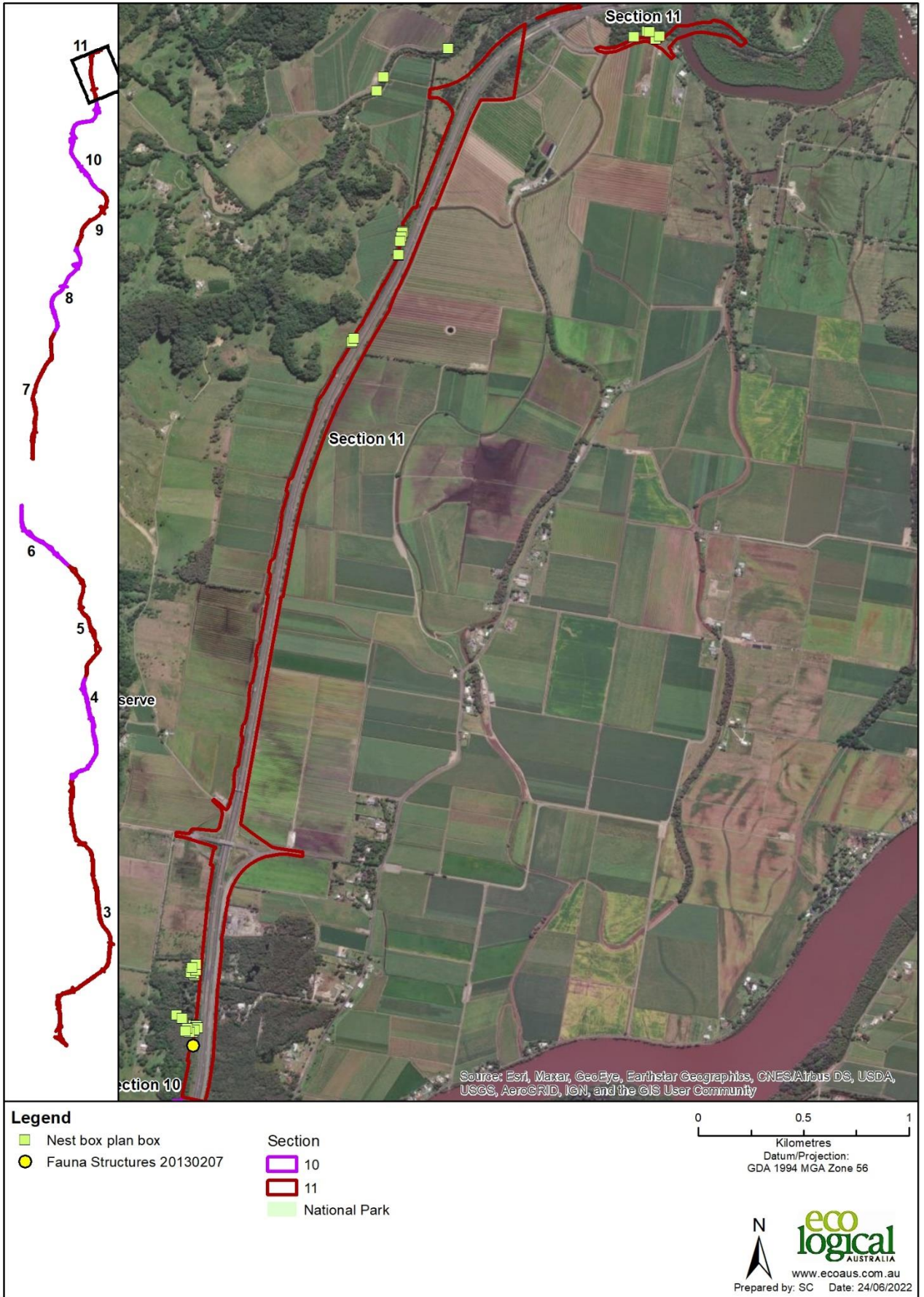


Figure 9: Section 11 of the W2B Pacific Highway upgrade project showing the location of nest boxes.



Photo 1: A front-entry hardwood glider nest box waiting to be installed in Section 3 of the W2B highway upgrade.



Photo 2: Marine ply nest boxes installed in Sections 3 – 11 of the W2B highway upgrade.



Photo 3: CYPLAS (recycled plastic) nest boxes installed in Sections 3 – 11 of the W2B highway upgrade.

Table 3: Box types and corresponding entrance sizes installed along the W2B alignment.

Box Type	Box Type Code	Entrance size (mm)
Antechinus	A	32
Barn Owl	BO	115-125
Cockatoo/Large Owl	Cock_Owl	150
Dollar Bird/Crimson Rosella	Dollar	75-80
Feathertail Glider	FTG	24
Glider (front-entry)	GLF	45-50
Glider (rear-entry)	GLR	45-50
King Parrot	KP	90
Kingfisher	Kf	50
Pardalote	Pard	38
Phascogale	BTP	50-55
Possum	Pos	110
Single-chamber Bat	B1	25
2-chamber Bat	B2	25-60 tapering
3-chamber Bat	B3	25 and 50-60

Box Type	Box Type Code	Entrance size (mm)
4-chamber Bat	B4	25-60 tapering
Small Parrot	SmP	65-70
Spotted-tailed Quoll	STQ	
Tree Creeper	TC	50
Wood Duck/Boobook	BOO	110

1.3.1 70 % installation

Data held by ELA indicated that, for the duration of monitoring throughout 2019-20, there were a total of 662 nestboxes that had been installed in the subject site (Table 4). This included nest boxes installed to provide short-term replacement habitat for fauna displaced by vegetation clearance, for a number of ancillary sites in Section 3 (20 boxes) and Section 6 (six boxes). Section 6 also includes eight boxes that had not been included in the NBMPs from Devils Pulpit, installed in October 2018 in response to design changes and additional clearing. No additional nest boxes were installed during 2019-20. Total monitored boxes does not equal total installed boxes for the following reasons and will be outlined in more detail in Section 3;

- Box has been cleared
- Box has been destroyed (termites / tree fall)
- Box has been stolen
- No access to box as a result of construction activities
- Box not located during monitoring

Table 4: Summary of 70% installation details for nest boxes required in Sections 3 – 11 of the W2B project.

Section	ELA install	Non ELA install	Total installed 2019-20
3A	12	0	12
3	253*	60*	313*
4	1	70	71
5	25	6	31
6	41*	0	41*
7	27	10	37
8 and 9	12	79	91
10 and 11	52	14	66
Total	423	239	662

* Includes additional nest boxes not included in NBMPs

1.3.2 100% nest box quota calculations

Nest Box Installation and Monitoring for Sections 3 – 11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B) required the supply, delivery, installation, monitoring and maintenance of 698 nest boxes of 22 different types along the 155 km Pacific Highway corridor between Woolgoolga and Ballina. The NBMPs provided guidance on the number and type of nest boxes required to be installed and nest box zones (sites). Of the 698 nest boxes required to be installed on Section 3-11 of the W2B project, 70% were installed prior to clearing and the remaining 30% installed post-clearing once the number of HBTs were compiled from data collected during clearing. The full addendum report can be found in Appendix B and outlines the process and justification for the methodology used to calculate the 100% quota of nest boxes.

A total of 662 of the required 698 nest boxes as identified in the Addendum Report (ELA 2021) were installed prior to clearing of vegetation for the W2B project. After applying the ratio of Est boxes : Est HBTs to the actual number of HBTs cleared (excluding HBTs cleared under variations), the combined total number of nest boxes remaining to be installed for the 100% install was 203. The single nest box required in Section 4 and Section 5 to fulfill the 100% quota will not be installed because the NBRZs are at capacity throughout these Sections. An additional 2 nest boxes was required to fulfil the 100% quota for the Avenue Road variation which was treated separately. Therefore, the number of nest boxes required to be installed were 204 (Table 5 and Table 6).

Table 5: Summary of 70% installation and 100% installation details for nest boxes in Sections 3 – 11 of the W2B project and the number of boxes monitored in Autumn and Spring 2021.

A	B	C	D	E	F	G	H	I
Section	**Required NBMP 100% (2021)	Total installed 2019-20 (70% installation)	Replacement boxes (Spring 2021)	Total installed Spring 2021 (100% installation)	Total installed (Spring 2021) (Column D+E)	Total Monitored (Autumn 2021)	Total Monitored (Spring 2021)	Total currently installed (Column C+E)
3A and 3	323	325*	26^	93	93	284	375	418
4	86	71	9	0	9	62	64	71
5	44	31	1	0	1	30	32	31
6	23	41*	6	2	8	32	36	43
7, 8 and 9	151	128	16	57	73	122	147	185
10 and 11	71	66	4	52	56	59	107	118
Total	698	662	62^^	204	240	589	761	866 +7^^ = 873

* Includes additional nest boxes not included in NBMPs

**As per Addendum Report (ELA 2021)

^ 26 Hollowhog

^^7 extra nest boxes than the quoted 55 replacement nest boxes.

Table 6: Proposed nest box types to be installed and/or created using Hollowhog (AH) to fulfil 100% quota and replacement boxes as per Addendum Report 2019-20 (ELA 2021).

Nest box type	100% Quota	Replacement boxes	Total
Antechinus	35	1	36
Phascogale	25	6	31
Wood duck	0	2	2
Cockatoo/Large Owl	1	7	8
Dollar Bird/Crimson Rosella	3	2	5
Feather Tail Glider	26	0	26
Galah	2	2	4
Glider (rear entry)	51	6	57
Kingfisher	0	3	3
Pardalote	0	1	1
Possum	28	16	44
2 Chamber Bat	17	4	21
3 Chamber Bat	14	0	14
4 Chamber Bat	0	0	0
Small Parrot	0	4	4
Spotted-tail Quoll	2	1	3
Total	204	55	259

NB: Where exact target nest boxes were not available, similar hollow size was installed (Refer to Table 8)

1.3.2.1 Artificial (carved) Hollows (Hollowhog)

Carved hollows are created by cutting a cavity into a dead or living tree and attaching a primarily wooden face plate or entry modifier to the opening of the cavity to ensure the entry size is specific to the target species. Cavities can be created using chainsaws or large drills (e.g. Hollowhog) that create an entrance and small cavity, which may be enlarged by animals.

Carved hollows are potentially suitable for a wide range of species as entrance and cavity size can be varied to suit the requirements of the target species. Carved hollows may offer a range of improvements on nest boxes including better temperature regulation, less maintenance, less cost and fewer visual impacts.

1.3.3 Carved hollows are still a relatively recent innovation. Monitoring of carved hollows will contribute to the development of this knowledge.

ArbPro were contracted to installed 26 Hollowhog throughout section 3 during October 2021 (Table 7). ArbPro used a Hollowhog tool to begin to create the cavity into the selected tree (**Photo 4**). A chisel was then used on the inner wood of the tree to extend the internal cavity, creating a hollow (**Photo 5**). ArbPro than attached the appropriately sized entrance of the artificial hollow to the outside of the cavity (**Photo 6**). These were installed at a height between 3 and 13 m.

Table 7 Artificial Hollow Type installed over section 3.

Artificial Hollow Type	Entrance Size	Type	Number
AHTopSmall	3.5 cm	Microbats	7
AHTopMed	4.5 cm	Small Gliders	7
AHBasSmall	3.5 cm	Microbats	9
AHBasLarge	5 cm	Microbats	3



Photo 4 Hollowhog Tool



Photo 5 Chiselled cavity



Photo 6 Entrance attached

The 204 nest boxes installed for the 100% quota comprised a mix of box types including 2 or 3 Chambered Bat Boxes, Antechinus, Brush-tailed Phascogale, Feathertail Glider, Glider Rear Entry and Possum / Large Glider (Table 8). To replace the 55 boxes reported as non-functional or missing in the 2019-20 report 26 Hollowhog and 36 nestboxes were installed (total of 62). Therefore 7 extra boxes were installed within this period (Table 8).

Table 8 Summary of actual nest box types installed and created using Hollowhog (AH) to fulfil 100% quota and replacement boxes in Addendum Report 2019-20 (ELA 2021).

Nest box type	100% Quota	Replacement boxes	Total
AHTopSmall	-	7	7
AHTopMed	-	7	7
AHBasSmall	-	9	9
AHBasLarge	-	3	3
Antechinus	36	1	37
Phascogale	20	3	23
Wood duck	0	2	2
Cockatoo/Large Owl	4	3	7
Dollar Bird/Crimson Rosella	3	2	5
Feather Tail Glider	22	0	22
Galah	4	0	4
Glider (rear entry)	50	3	53
Kingfisher	2	1	3
Pardalote	0	1	1
Possum	32	13	45
2 Chamber Bat	16	1	17
3 Chamber Bat	11	0	11
4 Chamber Bat	2	2	4
Small Parrot	0	4	4
Spotted-tail Quoll	2	0	2
Total	204	62	266

NB: AH – Artificial Hollow (Hollowhog)

2. Methodology

2.1 Nest Box Monitoring

ELA conducted the second Autumn and Spring inspections of the nest box allocation installed throughout the subject site in April, May, November and December 2021. These monitoring events correspond to Year 3 of the scheduled nest box monitoring inspections.

The 2021 autumn nest box inspection in Year 3 were carried out over 11 days between the 18 April to 25 May. The 2021 Spring nest box inspection in Year 3 were carried out over 22 days between the 16 November to the 13 December. Weather conditions during monitoring are provided in **Appendix A**.

Two teams of two staff (an ELA ecologist and an arborist) conducted each nest box inspection. Each box was initially visually inspected from the ground using binoculars to determine its condition, followed by inspection of the box contents using a GoPro Hero5 camera mounted to a telescopic extension pole. Arborists used the GoPro camera to inspect boxes installed above 8 m. Images from the GoPro camera were wirelessly streamed to a mobile and photo(s) of the contents were recorded. The data recorded for each nest box included:

- Date
- Weather conditions
- Observer
- Box number and location
- Box type code (see Table 3) and specifications
- Species using box or inferred from secondary evidence
- Number of individuals
- Age of individuals
- Sex of individuals (if possible)
- Evidence of breeding
- Signs of box use (scats, feathers, bone, hair, guano, skin, nests, shells, eggs, pellets, carcass, chewing, seeds, fruits, other)
- Pest species use (ants, bees, wasps, termites, rats, other)
- General condition of nest box and signs of damage/deterioration
- Required maintenance.

Boxes labelled as non-functional were not available to be used by fauna for any of the following reasons:

- Cleared
- Destroyed by fire
- Destroyed by termites
- Stolen
- Damaged/ destroyed by tree fall
- Persistently occupied by European Honeybees or Native Bees

Identification of fauna is based on the experience of the supervising ecologist with reference to standard field guides (e.g. Menkhorst and Knight 2004; Churchill 2008) as required. Except for some microbats, most fauna can be confidently identified from photographs/video footage. The identification of fauna signs is based on the ecologist's previous experience of hollow dependent fauna (HDF) nest characteristics and published information.

Host tree condition, surrounding landscape changes and required maintenance works since last monitoring event were also noted, if significantly different from that recorded at the time of installation.

In consultation with PC and Transport for New South Wales (TfNSW) where possible, damaged boxes and those inhabited by pest species were fixed or replaced *in situ*, otherwise repairs were noted and scheduled for completion during the following round of monitoring. Where pest species persistently occupied nest boxes, a decision was made regarding changing the design or leaving them *in situ* until the following monitoring inspection, based on evidence that some species (e.g. bees) only occupy boxes for a short period of time (Goldingay 2019). If the design of the box or its placement on the tree was required to be changed, the nest box was relocated during *in situ* or during the following monitoring inspection. If a nest box needed to be removed from site for repair and showed signs of use, an alternative box of the same or similar type will be installed in the same location, upon removal of the damaged box (in consultation with PC). A record of all repairs and changes to nest boxes is maintained. Maintenance works included:

- Repair of nest boxes
- Re-attachment of fallen undamaged nest boxes
- Removal of pest species (including possible retro-fitting of nest boxes to exclude pest species)
- Removal of excessive denning material (i.e. leaf litter)
- Replacement of fallen, degraded or damaged nest boxes
- Repositioning or relocation of dysfunctional nest boxes.



Photo 7: Examples of the type of evidence of nest box occupation recorded from the subject site. Spiral leaf nest (Glider).

2.2 Artificial Hollow Monitoring

An ELA ecologist and an arborist conducted each artificial hollow inspection over two days during Spring Monitoring. The content of each artificial hollow was inspected using a Burrowscope camera. Images from the burrowscope camera were used to record the content inside the artificial hollow. The data recorded for each nest box included:

- Date
- Weather conditions
- Observer
- Box number and location
- Box type
- Species using box or inferred from secondary evidence
- Number of individuals
- Age of individuals
- Sex of individuals (if possible)
- Evidence of breeding
- Signs of box use (scats, feathers, bone, hair, guano, skin, nests, shells, eggs, pellets, carcass, chewing, seeds, fruits, other)
- Pest species use (ants, bees, wasps, termites, rats, other)
- General condition of nest box and signs of damage/deterioration
- Required maintenance

Additional prior to spring 2021 monitoring cameras were set out prior for 3 months to observe the exterior of the Hollowhog. Any species captured by the cameras during this period were recorded.

3. Results

The results of 2021 autumn and spring nest box monitoring in regard to performance targets are provided below in Table 9. Performance targets 1 and 2 were not achieved in 2021 while performance targets 3 and 4 were achieved.

Table 9: Results of 2021 autumn and spring nestbox monitoring in regard to performance targets

Performance criteria	Target	Status
1. Use of nest boxes by a range of fauna species	Boxes inhabited by any fauna species within four years. Overall rates of use >50%.	Not achieved in Autumn or Spring with 26% and 25% of boxes used by native fauna respectively. However, 18 vertebrate species occupying nest boxes during the 2021 inspections.
2. Use of boxes by target species	≥5% occupancy of nest boxes by species for which the box was designed.	Not achieved. 4% boxes inhabited by species for which the box was designed during 2021.
3. Low rates of pest species usage	<15% of boxes	Achieved 10% Autumn and 11% Spring
4. Reduced maintenance and repair requirements	<10% boxes requiring repair or maintenance	Achieved 9% boxes (81) require and maintaince. Of the 81 nestboxes, 50 require replacement.

3.1 Performance Indicator 1: Boxes used by a wide variety of fauna species

During the 2021 Autumn monitoring event, 589 boxes (89%) out of the 662 installed across the subject site were monitored. There were 40 boxes that were non-functional during the Autumn 2021 monitoring event (Table 10). During the 2021 Spring monitoring event, 761 nest boxes (90%) out of the 847 installed were monitored (Table 11). There were 32 boxes that were non-functional and not available to be used by fauna of any species during the Spring 2021 monitoring event.

The results for Autumn are presented in (Table 10) and the results for Spring are presented in (Table 11). A total of 58 of 589 nest boxes (10%) were occupied in Autumn 2021 and 49 of 761 boxes (6%) were occupied in Spring 2021. Evidence of nest box usage without the presence of fauna was observed in 94 of 589 boxes (16%) in Autumn and in 145 of 761 monitored boxes (19%) in Spring. However it should be noted during the spring monitoring and installation period, 240 nest boxes were installed within an extremely short period of time before and during the spring survey period, therefore it is likely this timeframe did not give sufficient time for fauna to nest in or inhabit these boxes.

Evidence of usage can include nesting material, scratching on the outside of nest boxes, chewed entrances, the presence of depressions in the bark chips inside the box, animal skeletal remains, scats, feathers, owl pellets and egg shells.

The overall rate of useage (i.e. sum of boxes occupied and those featuring evidence of use in Autumn 2021 was 152 of 589 boxes (26%) and 194 of 761 boxes (25%) in Spring 2021. A summary of the overall rate of use for each season is provided in Table 10 and Table 11, and Figure 10 and Figure 11. The Autumn and Spring results both don't meet this performance indicator target and it is suggested that widespread and severe bushfires over spring and summer 2019-20 contributed significantly to this lower than expected result. The low overall usage rate could also be a result in the small period between the 100% installation and spring monitoring period. The lack of use of nest boxes by target species or species groups is also a feature common to other RMS nest box projects (Goldingay 2019) and is not unexpected.

Table 10: Nest box monitoring results – Autumn 2021

Section	Total installed boxes	Total boxes monitored	# Inhabited at time inspection	% Inhabited at time inspection	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Detected threatened species
3A	12	12	2	17	3	25	5	42	Nil
3	313	272	34	13	49	18	83	30	Squirrel Glider, Brush-tailed Phascogale, Eastern long-eared Bat
4	71	62	1	2	12	19	13	21	Nil
5	31	30	3	10	4	13	7	23	Eastern Long-eared Bat
6	41	32	1	3	7	22	8	25	Squirrel Glider
7	37	37	4	11	4	11	8	22	Squirrel Glider
8 and 9	91	85	3	4	10	12	13	15	Squirrel Glider
10 and 11	66	59	10	17	5	8	15	25	Squirrel Glider, Southern Myotis, Eastern Long-eared Bat
Total	662	589	58	10%	94	16%	152	26%	

Table 11: Nest box monitoring results – Spring 2021

Section	Total installed boxes	Total monitored boxes	# Inhabited at time of inspection	% Inhabited at time of inspection	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Detected threatened species
3A	12	17	1	6	0	0	1	6	Nil
3	380 [^]	358	26	7	66	18	92	26	Squirrel Glider
4	71	64	4	6	6	10	11	17	Nil
5	31	32	0	0	7	22	7	22	Nil
6	43	36	1	3	11	31	12	33	Nil
7	79	61	1	2	15	25	16	27	Nil
8 and 9	106	86	11	13	21	24	32	37	Squirrel Glider
10 and 11	118	107	4	4	19	18	23	21	Nil
Total	840 + 7 ^{^^} =847	761	49	6%	145	19%	194	25%	

[^]Not including 26 Hollowhogs (Refer to Section 3.6 for separate Hollowhog results)

^{^^}7 extra nest boxes installed as replacement boxes (Refer to Table 5).

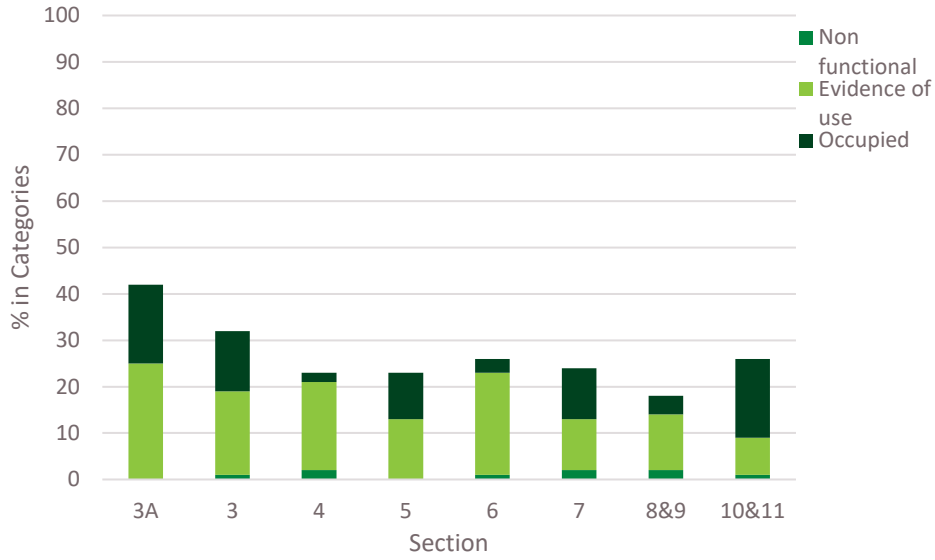


Figure 10 Overall use of nest boxes (%) in Autumn 2021 across Sections 3 to 11 of the W2B alignment.

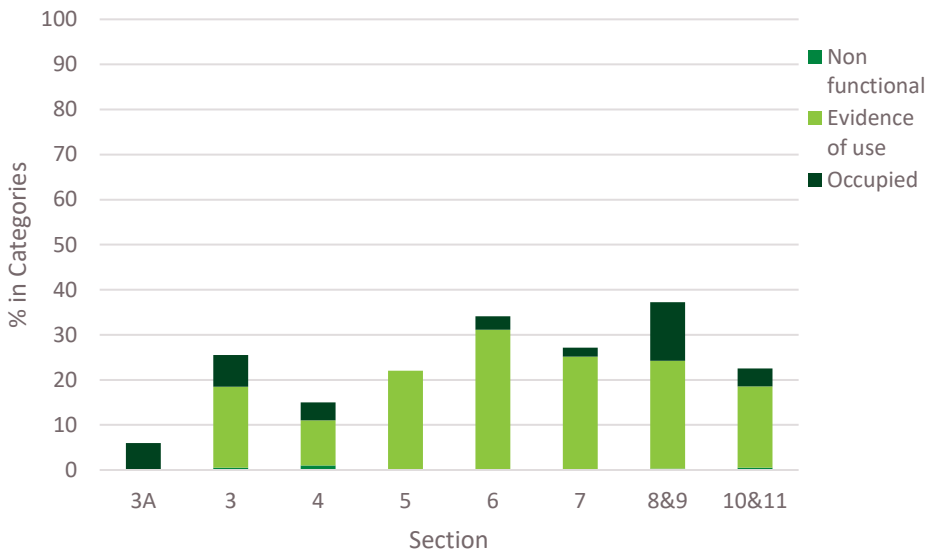


Figure 11: Overall use of nest boxes (%) in Spring 2021 across Sections 3 to 11 of the W2B alignment

Seventeen vertebrate species (three birds, five mammals, six microbats, two reptiles and one amphibian) were observed occupying nest boxes during the 2021 inspections (Figure 12). One invertebrate group (native bees) was also recorded. There were six species recorded during the 2021 monitoring that had not been recorded during the 2019-20 monitoring period and these were *Litoria peronii* (Peron's Tree Frog), *Chalinolobus gouldii* (Gould's Wattled Bat), *Chalinolobus morio* (Chocolate Wattled Bat), *Chenonetta jubata* (Australian Wood Duck), *Myotis macropus* (Southern Myotis) and *Trichosurus caninus* (Short-eared possum). There were two species recorded during 2019-20 that were not recorded during this monitoring period: *Ninox boobook* Southern Boobook and *Dendrelaphis punctulatus* Green Tree Snake. There have now been a total of 27 native vertebrate fauna species recorded occupying nest boxes since monitoring began in 2017. This figure includes 1 amphibian, five bird, 10 mammal, 8 bat and 3 reptile species.

There were 12 fauna species recorded in Autumn and 12 recorded in Spring, with six species recorded during both inspections. In Autumn 2021 the four threatened species recorded using boxes were Brush-tailed Phascogale, Eastern Long-eared Bat, Southern Myotis and Squirrel Glider. In Spring 2021, the only threatened species recorded using the boxes was the Squirrel Glider (Table 10 and Table 11). The four species listed as vulnerable under the BC Act are highlighted in **bold** in the lists below. The six species recorded in both Autumn and Spring were:

- *Aegotheles cristatus* Australian Owlet Nightjar
- ***Petaurus norfolcensis* Squirrel Glider (Vulnerable under the BC Act)**
- *Trichosurus vulpecula* Common Brushtail Possum
- *Trichosurus caninus* Short-eared Brushtail Possum
- *Litoria peronii* Peron's Tree Frog
- Native Bee (most likely *Tetragonula carbonaria*)

The remaining 12 species were recorded during one season only, and include 3 species listed as vulnerable under the BC Act:

- *Chalinolobus morio* Chocolate Wattled Bat
- *Chalinolobus gouldii* Gould's Wattled Bat
- *Chenonetta jubata* Australian Wood Duck
- *Morelia spilota* Carpet Python
- ***Myotis macropus* Southern Myotis (Vulnerable under the BC Act)**
- ***Nyctophilus bifax* Eastern Long-eared Bat (Vulnerable under the BC Act)**
- *Nyctophilus gouldi* Gould's Long-eared Bat
- *Nyctophilus* sp.
- *Petaurus breviceps* Sugar Glider
- ***Phascogale tapoatafa* Brush-tailed Phascogale (Vulnerable under the BC Act)**
- *Podargus strigoides* Tawny Frogmouth
- *Varanus varius* Lace Monitor.

The four species with the greatest number of individuals recorded within nest boxes across Autumn and Spring 2021 combined were:

- Common Brushtail Possum – 50 individuals (38 separate observations ranging from 1-2 individuals per box)
- **Squirrel Glider** – 34 individuals (15 separate observations ranging from 1-4 individuals per box)
- Gould’s Wattle Bat – 24 individuals (three separate observations ranging from 2-20 individuals per box)
- Eastern Long-eared Bat – 15 individuals (5 separate observations ranging from 1-6 individuals per box)

These four species accounted for 90 (80%) of 112 individual animals recorded using nest boxes during the Autumn 2021 inspections. During the Spring 2021 inspections 31 of the total of 61 individual animals (51%) recorded being Squirrel Glider or Common Brushtail Possum (Gould’s Wattle and Eastern Long-eared Bat weren’t recorded).

The species encountered the greatest number of times occupying nest boxes (regardless of the number of individuals) across Autumn and Spring 2021 were:

- Common Brushtail Possum
- **Squirrel Glider**

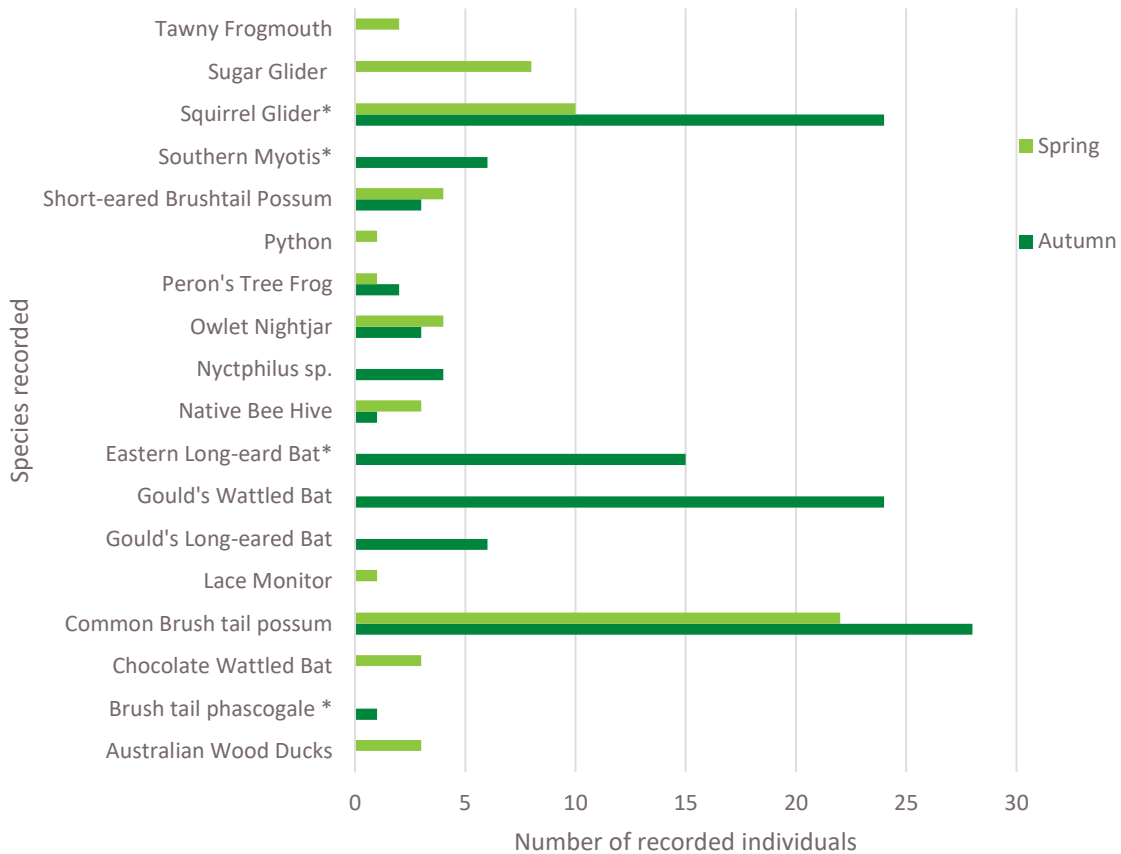


Figure 12 Species observed inhabiting nest boxes in 2021 within the W2B Sections 3 to 11. * Threatened species listed under the BC Act.

3.1.1 Evidence of breeding in nest boxes

There were several instances of family groups of Squirrel Gliders, Sugar Glider and Common Brushtail Possums occupying Cockatoo/Owl, Glider (front and rear entry), Boobook, Small Parrot, Phascogale and Possum timber and CYPLAS nest boxes (Photo 8). There was evidence of birds nesting within Cockatoo/Owl, Boobook and Possum CYPLAS and timber nest boxes, indicated by eggshells (potential Australian Owlet Nightjar, *Chenonetta jubata* (Australian Wood duck)).



Photo 8: Left: A Timber box containing a family of Squirrel Gliders, Spring 2021. Right: A Timber box containing one adult and one juvenile Common Brushtail Possum, Spring 2021.

3.1.2 Comparison of fauna recorded during clearing with fauna using nest boxes

Of the 32 species of fauna recorded during vegetation clearance in Section 3 (Table 12), eight of these species (22%) have been recorded occupying nest boxes in Section 3 since monitoring began in 2018. In section 3, an additional nine species have been recorded during monitoring that were not recorded during vegetation clearing giving a total of 17 species. If we include monitoring results for nest boxes in all sections, 29 (91%) of the 32 species have been recorded using nest boxes since monitoring began.

A total of 17 fauna species have been recorded using nest boxes in Section 3. A total of 29 fauna species (including Native Bees) have been recorded using nest boxes in Sections 3 – 11 of the W2B project since monitoring began (Table 12).

Over half (55%) of the fauna recorded in Section 3 during vegetation clearance were mammals (incl bats), with occupancy rates of 9% (110 occurrences in 1243 cleared trees) during the two stage clearing process.

Mammals accounted for over 90% of all fauna recorded occupying nest boxes in Section 3 during the 2021 monitoring year. Nest box occupancy rates for arboreal mammals (incl bats) in Section 3 during the 2021 monitoring period were 12% (32 of 272 monitored boxes) in Autumn and 7% (21 of 350 monitored boxes) in Spring. When combined with the results of the 2018 and 2019-21 monitoring year, the occupancy rate for mammals (incl bats) in nest boxes to date is 8% (140 occurrences in 1687 box checks).

Almost one third (32%) of all fauna recorded in Section 3 during vegetation clearance were small reptiles, largely comprised of skinks and Gecko's with occupancy rates of 5% (65 occurrences in 1243 cleared trees). It is notable that no small reptiles have been recorded during nest box inspections in any Section for the duration of the monitoring period, however Lace Monitors have been recorded using nest boxes (Photo 9). There were no nest boxes designed specifically for reptiles installed on the W2B Sections 3-11 project.

Birds accounted for only 2% of all fauna recorded in Section 3 during vegetation clearance with occupancy rates of <0.4% (5 occurrences in 1243 cleared trees). Birds accounted for 5% of all fauna recorded occupying nest boxes during the 2021 monitoring year in section 3. Nest box occupancy rates for birds in Section 3 during the 2021 monitoring period were >1% (2 of 2272 monitored boxes) in Autumn and >1% (1 of 350 monitored boxes) in Spring. When combined with 2018 and 2019-20 data, nest box occupancy rates for birds in Section 3 total 0.7% (12 occurrences in 1687 box checks) double the occupancy rate for birds recorded during fauna clearance. A completely different suite of birds was recorded in nest boxes than were recorded during vegetation clearance (Table 12).



Photo 9 A Lace Monitor in a nest in a timber nest box, Spring 2021.

Table 12: Comparison of fauna recorded during clearing with that recorded from nest box inspections

Species Name	Common Name	Fauna recorded during clearing surveys		Fauna recorded during nest box inspections 2017 – 2021		
		Section 3		Nest boxes S3	Nest boxes all sections	
Amphibians						
<i>Litoria caerulea</i>	Green Tree Frog	Y		N		N
<i>Litoria nasuta</i>	Rocket Frog	N		N		N
<i>Litoria peronii</i>	Peron's Tree Frog	N		Y		Y
	Unidentified Frog	Y		N		N
<u>Subtotal</u>		2		1		1
Birds						
<i>Aegotheles cristatus</i>	Australian Owlet Nightjar	N		Y		Y
<i>Chenonetta jubata</i>	Australian Wood Duck	N		Y		Y
<i>Cormobates leucophaea</i>	White-throated Treecreeper	N		Y		Y
<i>Ninox boobook</i>	Boobook Owl	N		Y		Y
<i>Philemon corniculatus</i>	Noisy Friarbird	Y		N		N
<i>Platycercus eximus</i>	Eastern Rosella	N		N		Y
<i>Podargus strigoides</i>	Tawny Frogmouth	Y		N		Y
<i>Todiramphus macleayii</i>	Forest Kingfisher	Y		N		N
<i>Trichoglossus moluccanus</i>	Rainbow Lorikeet	Y		N		N
	Unidentified Lorikeet	Y		N		N
<u>Subtotal</u>		5		4		6
Mammals						
<i>Acrobates pygmaeus</i>	Feathertail Glider	Y		N		Y
<i>Antechinus flavipes</i>	Yellow-footed Antechinus	Y		N		N
<i>Antechinus</i> spp.	Antechinus	Y		N		Y
<i>Chalinolobus gouldii</i>	Gould's Wattle Bat	Y		Y		Y
<i>Chalinolobus morio</i>	Chocolate Wattle Bat	Y		N		Y
<i>Myotis Macropus</i>	Southern Myotis	N		N		Y

Species Name	Common Name		Fauna recorded during clearing surveys	Fauna recorded during nest box inspections 2017 – 2021	nest boxes all sections
			Section 3	Nest boxes S3	
<i>Nyctophilus bifax</i> *	Eastern Bat	Long-eared	N	Y	Y
<i>Nyctophilus geoffroyi</i>	Lesser Long-eared Bat		N	Y	Y
<i>Nyctophilus gouldi</i>	Gould's Bat	Long-eared	N	Y	Y
<i>Nyctophilus spp.</i>	Unidentified eared Bat	Long-eared	N	Y	Y
<i>Petaurus breviceps</i>	Sugar Glider		Y	Y	Y
<i>Petaurus norfolcensis</i> *	Squirrel Glider		Y	Y	Y
<i>Petaurus 44rtifi</i> *	Greater Glider		Y	N	N
<i>Phascogale tapoatafa</i> *	Brush-tailed Phascogale		Y	Y	Y
<i>Pseudocheirus peregrinus</i>	Common Possum	Ringtail	Y	N	Y
<i>Rattus spp.</i>	Unidentified Rat		Y	N	Y
<i>Trichosurus caninus</i>	Short-eared possum		N	N	Y
<i>Trichosurus vulpecula</i>	Common Brushtail Possum		Y	Y	Y
	Unidentified microbat		Y	Y	Y
Subtotal			11	10	16
Reptiles					
<i>Boiga irregularis</i>	Brown Tree Snake		Y	N	N
<i>Cocinnia tenuis</i>	Bar-sided Forest Skink		Y	N	N
<i>Cryptophis nigrescens</i>	Eastern Small-eyed Snake		Y	N	N
<i>Cyclodomorphus gerrardii</i>	Pink-tongued Skink		Y	N	N
<i>Dendrelaphis punctulatus</i>	Green Tree Snake		Y	Y	Y
<i>Egernia cunninghami</i>	Cunningham's Skink		N	N	N
<i>Eulamprus martini</i>	Martin's Skink		N	N	N
<i>Lampropholis delicata</i>	Delicate Skink		Y	N	N
<i>Lialis burtonis</i>	Burton's Legless Lizard		Y	N	N

Species Name	Common Name	Fauna recorded during clearing surveys		Fauna recorded during nest box inspections 2017 – 2021		
		Section 3		Nest boxes S3	Nest boxes all sections	
<i>Liopholis whitii</i>	White's Skink		N	N	N	
<i>Morelia spilota</i>	Carpet Python		Y	N	Y	
<i>Nebulifera robusta</i>	Robust Velvet Gecko		Y	N	N	
<i>Pogona barbata</i>	Eastern Bearded Dragon		Y	N	N	
<i>Varanus varius</i>	Lace Monitor		Y	Y	Y	
	Unidentified Leaf-tailed Gecko		Y	N	N	
	Unidentified Skink		Y	N	N	
	Unidentified Gecko		Y	N	N	
<u>Subtotal</u>			12	2	3	
Invertebrates						
	Native Stingless Bee		Y	N	Y	
<i>Apis mellifera</i>	European Honey Bee		Y	N	Y	
<u>Subtotal</u>			2	0	2	
Total species			32	17	29	

3.2 Performance Indicator 2: Boxes occupied by target fauna species

There were a total of 56 records (4%) of target fauna species occupying nest boxes designed for that species or fauna group in 2021. **Evidence of use by target species was found in 92 (7%) boxes with an overall nest box usage rate by target species of 148 boxes (11%)** (Table 13). Evidence of use was not always possible to attribute to target fauna species because of the difficulty in accurately assigning incomplete or old leaf nests to Antechinus, Feathertail Glider, Sugar and Squirrel Glider species. In the majority of cases where nest box occupancy was recorded, nest boxes were occupied by non- target fauna species. Seven box types recorded occupancy by target species and these were:

- Glider front and rear entry boxes – Sugar and Squirrel Glider
- Possum / Large Glider boxes – Common Brushtail Possum, Short-eared Brushtail Possum, Squirrel Glider
- Microbat boxes (Single chamber, 2 chamber, 3 chamber and 4 chamber) – Eastern Long-eared Bat, Gould's Long-eared Bat, *Nyctophilus sp.*, Southern Myotis and Gould's Wattle Bat

Five box types achieved the recommended performance indicator of $\geq 5\%$ this included, Glider (rear entry), Possum, Single Chamber Bat, 2-Chamber Bat, 3-Chamber Bat. All other box types recorded occupancy rates equal to or lower than 5% when autumn and spring results were combined. When overall usage rates (occupancy + evidence of use) were considered seven box types were $>5\%$,

Antechinus, Glider rear and front entry, Possum, Single-chamber bat, 2-chamber bat, 3-chamber bat were also considered to be relatively successful.

Four of the 24 target threatened fauna species were recorded using nest boxes and all four are listed as vulnerable under the BC Act:

- **Brush-tailed Phascogale***
- **Eastern Long-eared Bat***
- **Squirrel Glider*.**
- **Southern Myotis***

Eastern Long-eared Bats were recorded on multiple occasions in autumn, using Single chamber, 2 chamber and 3 chamber bat boxes in section 3, 4 and 10-11. Eastern Long-eared Bats occupied both timber and CYPLAS boxes. Southern Myotis were record within timber 2-chamber bat box within section 11 adjacent to Emigrant Creek. Squirrel Gliders were recorded on multiple occasions in both autumn and spring in half of the Sections, except for Section 3, 4, 6, 7, 8-9, 10-11 and used both timber and CYPLAS nest boxes. Squirrel Gliders were recorded predominantly using Glider front-entry and rear-entry boxes, but also inhabited Brush-tailed Phascogale, Possum, Small Parrot and Treecreeper boxes). Sugar Gliders were also recorded predominantly using Glider front-entry and rear-entry boxes with one record of Sugar glider inhabiting Small Parrot boxes. There was one instance of Brush-tailed Phascogale evidence (nest, scat) recorded in a Brush-tailed Phascogale box in section 3. Brush-tailed Phascogale was also recorded occupying a Glider front entry box, during the Autumn inspections in Section 3.

Nest box type and associated rates of occupancy collected from nest box inspections carried out across the two periods are summarised in Table 13. A total of 1309 nest box inspections were able to be carried out for 847 boxes, this is excluding unknown box types. The majority of boxes were inspected twice (Spring and Autumn), but 50 boxes were non-functional during the monitoring period and were not available for use by fauna or able to be inspected as a result of being cleared, subject to fire, destroyed by termites or tree fall, occupied by European Bees. ELA notes that nest box type was not recorded for 29 boxes, and these data have not been included in this analysis. One of these 29 boxes of unknown type contained a Brushtail Possum and another two were inhabited by Australian Owlet Nightjar, seven boxes showed evidence of use.

3.2.1 Birds

Of the bird boxes (Barn Owl, Boobook/Wood Duck, Cockatoo/Owl, Dollarbird/Crimson Rosella, Kingfisher, King Parrot, Pardalote, Small Parrot and Treecreeper) none were occupied by the target bird species and only one box type contained evidence for the target species during the Autumn and Spring 2021 survey periods (Table 13). Owl feathers and eggs were recorded in two found in six Cockatoo/Owl boxes.

Other bird species and/or evidence of their presence were recorded within bird boxes not designed for the species. The Australian Owlet Nightjar and Tawny frogmouth were found in a small parrot box. Australian Wood Duck eggs and remnants were observed in Cockatoo/Owl Box. Other bird species occurred in other boxes including glider (rear-entry) and possum boxes. A total of three bird species were recorded during the 2021 monitoring event occupying nest boxes.

Bird boxes monitored in 2021 were also occupied by or showed evidence of occupation by Common Brushtail Possums, Short-eared Brushtail Possum, Squirrel Gliders*, Sugar Gliders and *Nyctophilus* sp. (Table 13).

3.2.2 Bats

All four bat box types recorded occupancy of target species (Table 13). Three of the four types of bat boxes (Single-chamber, 2-chamber and 3-chamber) all recorded occupancy by one of the targeted threatened bat species, Eastern Long-eared Bats. Another threatened targeted species Southern Myotis was recorded in 2-chamber box. Gould's Long-eared Bats occurred in single-chamber and 2-chamber, Gould's Wattled Bat occurred in a 3-chamber and 4-chamber, *Nyctophilus* sp. In 3-chamber boxes. Six species of bat were recorded during the 2021 monitoring surveys, one species wasn't recorded within a bat box. Chocolate Wattled Bat was recorded occupying a Feathertail Glider Box.

During the 2021 survey period the threatened Eastern Long-eared Bat (vulnerable under the BC Act) occupied three boxes (CYPLAS and timber), with abundance ranging from one to six individuals. Gould's Long-eared Bat also occupied four boxes (CYPLAS and timber), with abundance ranging from one to two individuals in each. In some cases it was not possible to identify the species of microbat from camera images. One non target species was recorded using bat boxes during 2021 survey period.

A total of six Southern Myotis were recorded during the 2021 survey period. The Southern Myotis were observed within a timber 2-chamber box which had been installed between 5-7 m on a Forest Red Gum within section 11. The bat box is adjacent to Emigrant Creek.

These results are relatively consistent with recent studies of bat box efficacy, which indicate that common and widespread urban adapted bat species tend to occupy boxes with other bat species making little to no use of boxes. The Eastern Long-eared Bat is the obvious exception in this case (Griffiths et al. 2017 and 2018; Rueegger et al. 2019a) but is in the same genus as two other common *Nyctophilus* species known to use bat boxes and shares similar roosting ecology with these species. It is particularly notable that threatened Eastern Long-eared Bat continues to use nest boxes of both timber and CYPLAS construction. It is well known that uptake of bat boxes can take several years to occur. Occupancy levels have decreased since the 2019-20 monitoring events with only 3-chamber bat box achieving the original performance indicator target of greater than 10% occupancy.

3.2.3 Arboreal mammals

There were no *Antechinus* occupying *Antechinus* boxes during inspections in 2021 (Table 13). Many *Antechinus* boxes showed evidence of former use by *Antechinus*, in the form of loose leaf nesting material. There were also a number of leaf and bark nests that could have been attributed to a range of other species including Brush-tailed Phascogale, Feathertail Glider, Sugar Gliders or Squirrel Gliders, although the entrance size of the *Antechinus* box is generally too small for anything but Feathertail Gliders or juveniles of the other species mentioned to enter.

Feathertail Glider boxes were not occupied by Feathertail Gliders during Autumn or Spring nest box inspections in 2021 (Table 13). Three Chocolate Wattle Bat recorded occupying one Feathertail Glider boxes.

Possum boxes showed the highest rates of occupancy by arboreal mammals amongst all arboreal mammal box types. Approximately 9% of Possum boxes were occupied in 2021, predominately by the

Common Brushtail Possum but also Short-eared Brushtail Possum. Evidence of use by possums was 4% and mainly consisted of loose leaves pulled into the box. Occupancy and evidence of range of non-target species was recorded in Possum boxes including the Australian Owlet Nightjar, Australian Wood Duck (eggs), Lace Monitor, Squirrel Glider, Sugar Glider and Tawny Frogmouth.

Glider boxes (front and rear entry) showed the second highest rates of occupancy by arboreal mammals. A total of 4% of Glider front entry and 6% of Glider rear entry box types were occupied by Sugar Glider and/or Squirrel Gliders in 2021 (Table 13). Evidence of usage in 2021 was 32% for Glider front entry and 22% for Glider rear entry boxes respectively, largely comprising leaf nesting material. As mentioned above there is some difficulty in accurately assigning incomplete or old leaf nests to Antechinus, Feathertail Glider, Sugar and Squirrel Glider species so the figures for evidence of use are to be read with caution. Non target species reported in Glider boxes included Common Brushtail Possum, Short-eared Brushtail Possum, Brushtail Phascogale, Person's Tree Frog, Lace Monitor and Native bees.

Brush-tailed Phascogale boxes recorded no targeted species occupancy and 2% evidence of targeted species usage. Brush-tailed Phascogale boxes mainly found to contain leaf nests which were often attributed to Glider usage (Table 13).

There was no evidence of use in the single Spotted-tailed Quoll box in either Autumn or Spring 2021. There has not been any documented records of Spotted-tailed Quolls inhabiting nest boxes reported in any scientific literature to date.

Table 13: Nest box type and rates of occupancy per target species following nest box inspections undertaken in Autumn and Spring 2021 on Sections 3 – 11 of the W2B project.

Box Type	# installed	boxes # functional boxes	non-# boxes	Functional # boxes	# times boxes checked in 2021	# occurrences of target species occupying boxes	% occupancy by target species	evidence of use by target species	% evidence of use by target species	Overall usage by target species	% Overall usage by target species	All species detected (occupancy and evidence of use)
Antechinus	33	1	62	86	0	0	11	13	11	13	Antechinus (nest), Sugar/Squirrel Glider (nest)	
Barn Owl	0	3	12	21	0	0	0	0	0	0	Brushtail Possum	
Boobook / Wood duck	2	0	4	6	0	0	0	0	0	0	Brushtail Possum	
Cockatoo/Large Owl	8	7	54	90	0	0	2	2	2	2	Brushtail Possum, Woodduck (eggs), Short-eared Brushtail Possum, Owl (feather, nest, eggs), Sugar/Glider (scat, nest)	
Dollar Bird/Crimson Rosella	5	0	10	11	0	0	0	0	0	0	Native bee hive	
Feather Tail Glider	22	1	31	35	0	0	0	0	0	0	Chocolate wattle bat	
Galah	4	0	4	4	0	0	0	0	0	0	Nil	
Glider (front entry)	1	2	40	77	4	5	25	32	29	38	Squirrel Glider, Sugar Glider, Brush tail phascogale, Short eared Brushtail Possum	
Glider (rear entry)	57	4	119	175	11	6	39	22	50	29	Squirrel Glider, Sugar Glider, Brushtail Possum, Bird (stick nest), Native Bee Hive, Peron's Tree Frog	
Kingfisher	3	1	10	18	0	0	0	0	0	0	Sugar / Squirrel Glider (nest)	
King Parrot	0	0	4	8	0	0	0	0	0	0	Sugar / Squirrel Glider (nest), Australian green tree frog (Scat)	
Pardalote	2	1	9	17	0	0	0	0	0	0	Sugar / Squirrel Glider (nest)	
Phascogale	19	3	53	81	0	0	1	1	1	1	Squirrel Glider, Sugar / Squirrel Glider (nest), Phascogale (nest, scat)	
Possum	43	15	210	337	29	9	14	4	43	13	Squirrel Glider, Sugar/Squirrel Glider (nest), Brushtail Possum, Woodduck (eggs), Short-eared Brushtail Possum, Owllet nightjar, Tawny Frogmouth, Lace Monitor	
Single Chamber Bat	1	1	17	32	2	6	0	0	2	6	Gould's Long-eared Bat, Sugar/Squirrel (nest)	
2 Chamber Bat	17	1	51	81	5	6	0	0	5	6	Eastern Long-eared Bat, Gould's Long-eared Bat, Southern Myotis	
3 Chamber Bat	9	0	25	35	4	11	0	0	4	11	Eastern Long-eared Bat, Gould's Wattle Bat, Nyctophilus sp., Carpet Python	
4 Chamber Bat	4	1	21	38	1	3	0	0	1	3	Eastern Long-eared Bat, Gould's Wattle Bat	
Small Parrot	4	4	72	137	0	0	0	0	0	0	Squirrel Glider, Native Bee Hive, Tawny Frog Mouth, Owllet Nightjar, Sugar/Squirrel Glider (Nest), Nyctophilus sp.	
Spotted-tail Quoll	2	1	2	3	0	0	0	0	0	0	Nil	
Tree Creeper	0	3	6	17	0	0	0	0	0	0	Squirrel Glider, Sugar/Squirrel Glider (nest)	
Totals	236	49	816	1309	56	4	92	7	148	11		
*Unknown	6	1	29	41	0	0	0	0	0	0	Brushtail Possum, Owllet Nightjar, Sugar / Squirrel Glider (nest)	

*29 boxes did not have nest box type recorded and are not included in this analysis.

3.3 Performance Indicator 3: Pest species

The performance indicator target of <15% pest species uptake was met with European bees the only exotic pest species detected. European bees were uncommon, only recorded in section 4, 8-9 and 10-11. During Autumn inspection 3 boxes recorded European bees and three boxes occupied in Spring.

Other native pest species which were recorded in nest boxes were:

- ants
- invertebrates (i.e. spiders)
- termites
- wasps.

There was a total of 58 (10%) nest boxes occupied by these pest species during the Autumn 2021 monitoring inspections, and 86 (11%) occupied by pest species during the Spring 2021 inspections (Table 14 and Table 15). Where possible pest species were dealt with in situ by leaving the box lid open between monitoring inspections (discouragement for ants / wasps) and clearing old nests / hives out. The five species

Pest species were recorded in all Sections. Rates of pest species uptake varied between 0 – 41% of boxes per section across the subject site. Section 10—11 recorded rates of pest species uptake in Autumn that exceeded performance targets of (<15%). In Spring 2021 Section 3A and 5 exceeded performance targets of (<15%).

Ants were the most commonly recorded pest species to occur in most Sections for 2021 with 31 (5%) of nest boxes occupied in Autumn and 43 (5%) occupied in Spring 2021 (Table 14 and Table 15). Ants occurred in a broad range of box types including single-chamber Bat, Antechinus, Brush-tailed Phascogale, Feathertail Glider, Glider (front and rear entry), Barn Owl, Boobook/Wood duck, Cockatoo/Large Owl, Tree Creeper, Pardalote, Possum and Small Parrot. Majority of ants were recorded in timber boxes and only half the number of ants recorded in CYPLAS boxes (Photo 10).

Termites were the second greatest pest issue and only occurred in timber boxes, with 22 (4%) of boxes recorded in Autumn and 18 (2%) in Spring.

European bees were uncommon, only recorded in section 4, 8-9 and 10-11. During Autumn inspection 3 boxes recorded European bees and three boxes occupied in Spring. No other sections recorded European Bees. European Bees were recorded using a Small Parrot Cockatoo/Owl, Glider front entry and Dollar bird box types. One of the boxes occupied by European bees in Autumn continued to be occupied by bees in Spring.

Wasps and wasp nests (largely mud wasps) were recorded in nest boxes in Section 3 with two boxes (<1%) showing evidence of wasp occupation in Autumn. Spring recorded a higher number of boxes containing wasp with 11 (<1%) boxes over Section 3, 4 and 7. Wasps occurred in single-chamber Bat, Glider rear entry, Brushtail Phascogale and Possum boxes. Wasps occupied both CYPLAS and timber boxes. There was one box occupied by wasps in Autumn that was still occupied by wasps in Spring.

Invertebrates (i.e. spiders) were recorded in nest boxes in Sections 3A, 3 and 7 in Spring. Spiders were recorded in 12 (14%) Boxes in spring but not in Autumn. Invertebrates occupying a range of box types (

Antechinus, Brushtail Phascogale, 2-chamber Bat, Feathertail Glider, Possum and Small Parrot) of both CYPLAS and timber construction (Photo 10).

There were numerous instances recorded during 2021 monitoring inspections of fauna using a nest box after pest species had left the box, which shows that the current maintenance practices of leaving bee hives, ant and wasp infestations where safe and practical to do so during monitoring are effective ongoing practices.

Table 14: Pest species uptake of nest boxes in Sections 3 – 11 of the W2B project as recorded during Autumn 2021 inspections.

Section	Ants	Bees	Inverts	Termites	Wasps	Total	# Monitored	% Uptake
3A	0	0	0	0	0	0	12	0
3	11	0	0	4	2	17	272	6
4	1	1	0	6	0	8	62	13
5	2	0	0	1	0	3	30	10
6	3	0	0	1	0	4	32	13
7	0	0	0	1	0	1	37	3
8 and 9	11	1	0	3	0	14	85	16
10 and 11	3	1	0	6	0	10	59	17
Total	31	3	0	22	2	58	589	10

Table 15: Pest species uptake of nest boxes in Sections 3 – 11 of the W2B project as recorded during Spring 2021 inspections.

Section	Ants	Bees	Inverts	Termites	Wasps	Total	# Monitored	% Uptake
3A	4	0	3	0	0	7	17	41
3	21	0	8	5	9	43	358	12
4	0	2	0	5	1	8	64	13
5	5	0	0	0	0	5	32	16
6	3	0	0	1	0	3	36	8
7	0	0	1	1	1	3	61	5
8 and 9	7	0	0	3	0	10	86	12
10 and 11	3	1	0	3	0	7	107	7
Total	43	3	12	18	11	86	761	11

3.4 Performance Indicator 4: Repair and Maintenance

Performance indicator 4 was achieved with less than 10% of boxes requiring maintenance or repairs. 81 nest boxes (9%) required repair and maintenance out of the 847 nestboxes. 51 nest boxes (6%) were required to be replaced and 30 nestboxes (3%) required maintenance. 14 nestboxes (2%) required maintenance (repositioning on the host tree or lid propping / closing). Where possible and where it was safe to do so, maintenance was completed *in situ* during nest box inspections.

Seventeen boxes (2%) had some damage (from termites, fire or fauna chewing around the entrance, or other damage) but remained functional. Where possible and where it was safe to do so, maintenance was completed *in situ*.

The majority, 21 (2%) of boxes needing to be replaced resulted from loss due to severe bushfires, followed by 14 (2%) boxes that were lost due to termites. The material and box type that require replacing are shown in Table 17.



Photo 10: left: Timber box infested with ants, Spring 2021. Right: Timber box infested with termites, Spring 2021.

Table 16: Maintenance, repair and replacement required following 2021 nest box inspections on Sections 3 – 11 of the W2B project.

Section	Damaged / Non-functional – replace					Maintenance / Box condition						
	2019 Fires	Termites	Tree fall	Cleared	Bees	Repositioned	Termites present box functional	Scorched by fire box functional	Lid opened/closed	Chewing box functional	Other	
3A	0	0	0	0	0	0	0	0	0	0	0	
3	0	4	0	5	0	2	6	0	4	0	2	
4	0	5	0	4	1	1	1	0	0	0	0	
5	0	0	0	0	0	0	1	0	0	0	0	
6	7	0	0	1	0	1	0	1	0	0	0	
7	13	0	0	1	0	1	1	0	1	0	0	
8	0	1	0	1	0	1	3	0	2	0	0	
9	0	0	0	0	0	0	0	0	0	0	0	
10	1	4	0	1	0	0	2	0	0	0	0	
11	0	0	0	0	2	1	0	0	0	0	0	
Sub-total	21	14	0	13	3	7	14	1	7	0	2	
Total				51					30			

Table 17: Nest box types and construction material for the 51 nest boxes that need to be replaced on W2B, Section 3-11.

Box Type	Number of boxes to be replaced	Total Timber	Total CYPLAS
A	1	1	
Barn Owl	3	2	1
Cockatoo/Large Owl	7	6	1
FTG	1	1	
Glider (front entry)	2	2	
Glider (rear entry)	5	4	1
Kingfisher	1	1	
Pardalote	1	1	
Phascogale	3	2	1
Possum	15	8	7
Single Chamber Bat	1	1	
2 Chamber Bat	1	1	
4 Chamber Bat	1	1	
Small Parrot	4	3	1
Spotted-tail Quoll	1	1	
Tree Creeper	3	3	
Unknown	1	1	
total	51	39	12

3.5 Comparison of the performance of timber and CYPLAS nest boxes

3.5.1 Occupancy by native fauna

Of the current 847 nest boxes, 366 were made from CYPLAS (43%) and 530 (63%) were made from timber. A total of 436 timber boxes were monitored during autumn and spring 2021. A smaller number (153) of CYPLAS boxes were inspected during autumn than spring (323).

A slightly larger proportion of CYPLAS boxes were found to be occupied by fauna both in autumn of 2019 and 2021. In Autumn 2021 monitoring 9% of the 436 timber boxes monitored were recorded to be occupied by fauna compared to 13% CYPLAS boxes of the 153 CYPLAS boxes monitored. Whereas in spring timber boxes recorded 9% of 436 boxes monitored and CYPLAS boxes 3% of the 325 CYPLAS boxes monitored.

While the proportion of timber boxes occupied in autumn and spring was found to be similar, the proportion of occupied CYPLAS boxes appear to differ between seasons, with a 10% drop in box occupancy between autumn and spring in 2021 (Figure 13). A similar drop in the proportion of occupied CYPLAS boxes was observed in the last round of nest box monitoring in 2019 where the proportion of occupied boxes dropped by 9% between autumn and spring while occupancy of timber boxes differed by only 2% between seasons. Minimal differences in occupancy between material types were observed in the first round of nest box monitoring in 2018.

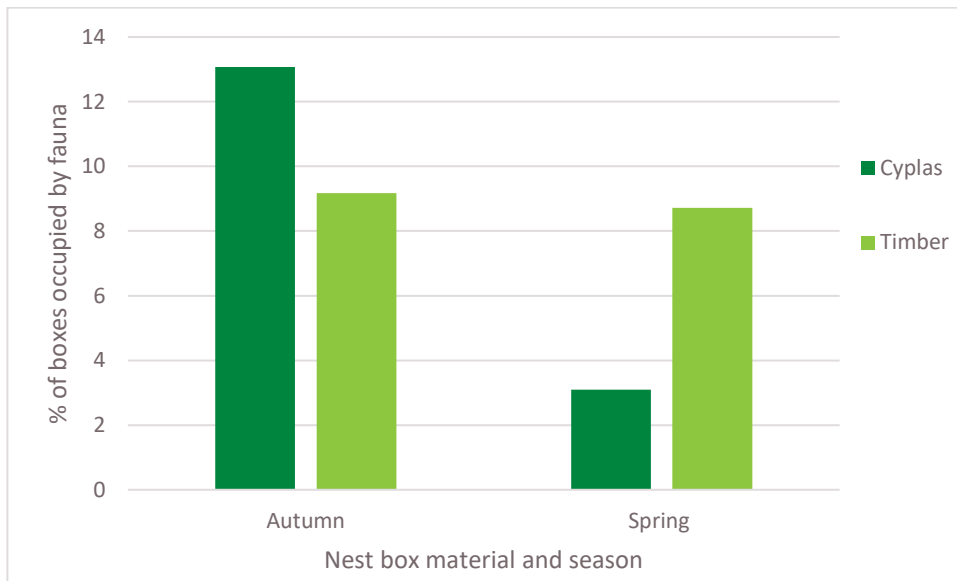


Figure 13 Comparison of overall rates occupied boxes for timber and CYPLAS nest boxes as recorded during Autumn and Spring 2021

3.5.2 Variety of fauna

A total of 27 vertebrate species have been recorded using nest boxes over all monitoring years. Seventeen vertebrate species were recorded in 2021, five of these species were only recorded in CYPLAS and six were only recorded in Timber (Table 18). Two of the four threatened species directly recorded in nest boxes during the monitoring program (Squirrel Glider and Eastern Long-eared Bat) have been recorded in boxes of both materials.

During 2021 the number of fauna species recorded occupying both CYPLAS and timber boxes was similar, despite the larger number of timber boxes. The same number of fauna species (8) were recorded inside CYPLAS and in timber boxes during Autumn. Similarly, six fauna species were recorded in CYPLAS during Spring compared to eight species in the larger number of timber boxes (Table 18).

Evidence of birds utilising nest boxes for breeding was recorded. Australian Woodduck was recorded breeding in both CYPLAS and timber boxes nest boxes, although the majority of records for breeding birds were from timber boxes. Possible Powerful Owl eggs and feathers were recorded in a CYPLAS Cockatoo/Owl box in section 10.

Table 18: List of species occupying timber and CYPLAS boxes during Autumn and Spring nest box inspections.

Common name	Autumn		Spring	
	CYPLAS	Timber	CYPLAS	Timber
Australian Owlet Nightjar	Y	Y		Y
Australian Wood Duck			Y	
Brush-tailed Phascogale*	Y			
Carpet Python				Y
Chocolate wattled bat				Y
Common Brushtail Possum	Y	Y	Y	
Eastern Long-eared Bat*	Y	Y		
Gould's Long-eared Bat	Y	Y		
Gould's wattled bat		Y		
Lace Monitor				Y
Nyctophilus sp.		Y		
Peron's Tree Frog	Y		Y	
Short-eared Brushtail Possum	Y		Y	Y
Southern Myotis*		Y		
Squirrel Glider*	Y	Y		Y
Sugar Glider				Y
Tawny Frogmouth			Y	Y

* Listed as vulnerable under the BC Act

3.5.3 Pest species

The rates of uptake by pest species in CYPLAS boxes was 24 occurrences in 476 box inspections (5%) (Autumn and Spring combined) (Table 19). There were four pest species groups recorded in CYPLAS boxes (ants, bees, invertebrates and wasps), with ants the most commonly recorded pest. Rates of pest species uptake in timber boxes were 119 occurrences in 874 (14%) box inspections (Autumn and Spring combined) (Table 19). Timber boxes recorded all five pest species groups (including termites) with ants still the most commonly recorded pest. These figures meet the performance indicator target of <15% pest species uptake.

In terms of pest species uptake, CYPLAS boxes performed much better than timber boxes, largely due to a complete lack of termites using CYPLAS boxes and greatly reduced rates of ants, bees and invertebrates (Table 19 and Figure 14). Overall the rates of pest species uptake in timber was greater than CYPLAS in Autumn and Spring (Figure 14).

Table 19: Rates of pest species uptake in timber and CYPLAS boxes following nest box inspections in Autumn and Spring 2021 on Sections 3 – 11 of the W2B project.

Box type	Ants	Bees	Invertebrates	Termites	Wasps	Total	# Monitored	% Uptake
Timber	62	5	8	40	4	119	874	14
CYPLAS	11	3	4	0	9	24	476	5

3.5.1 Repair and maintenance

Repair and maintenance requirements for CYPLAS boxes were lower than for timber boxes. Throughout 2021 monitoring, only 12 (2 %) CYPLAS boxes required replacement compared to 39 (7%) timber boxes.

Fire destroyed 21 boxes (CYPLAS and timber) and scorched one boxes which required maintenance. Fourteen timber boxes required replacing due to being destroyed by termites. The remainder of issues comprised tree fall damage, repositioning or lid propping due to infestation by pest species.

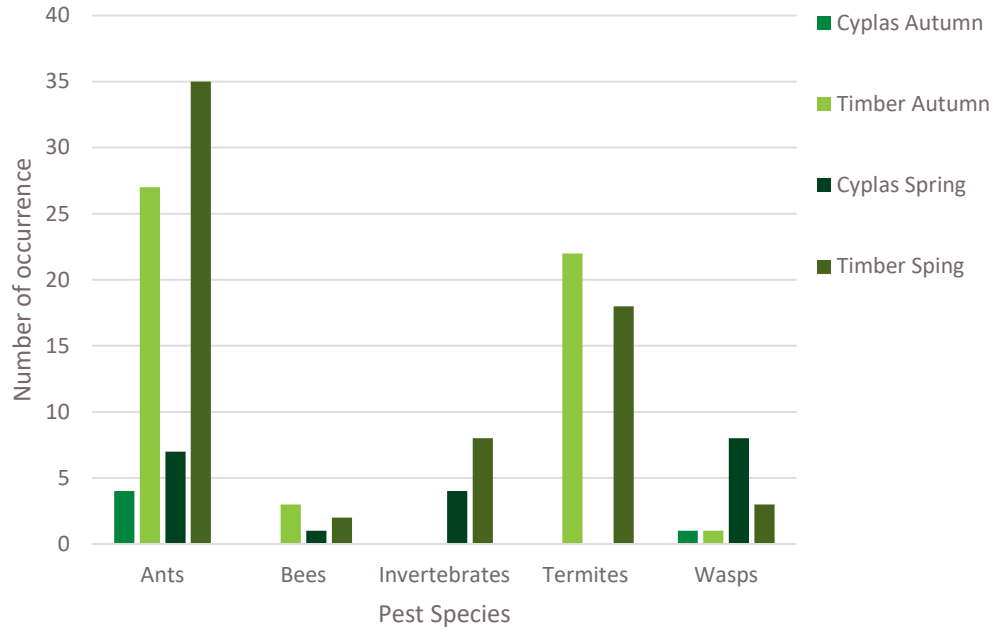


Figure 14 Number of timber and CYPLAS boxes containing pest species following nest box inspections in Autumn and Spring 2021 on Sections 3 – 11 of the W2B project.



Photo 11: A Short-eared Brushtail Possum (melanistic form) in a CYPLAS nest box, Spring 2021

3.6 Hollowhog (Artificial (carved) Hollows)

Hollowhog were installed at the end of October 2021. Hollowhog were installed over section 3 in two Nest Box Replacement Zones (NBRZ); 14 installed in NBRZ 19 Pine Bush and 12 installed in NBRZ 4/5 on Old Six Mile Lane. Spring 2021 is the first round of inspections forming the baseline data. No species were recorded occupying the Hollowhog Homes during the Burrow scope inspections in 2021. However, three species (Squirrel Glider, Brushtail Possum and Sugar Glider) were observed inspecting the hollows (Table 20). The three species recorded were captured inspecting the hollow (Photo 12)

Table 20 Hollowhog home baseline survey 2021.

Number	Location	Type	Date monitored	Burrow scope (within hollow)	Camera (outside hollow)	Pest Species
900	S 3 NBRZ 19 Pine Brush SF	AHTop Med	12/12/2021	Nil		
901	S 3 NBRZ 19 Pine Brush SF	AHTopS mall	12/12/2021	Nil	Squirrel Glider, Brushtail Possum, Sugar Glider	
902	S 3 NBRZ 19 Pine Brush SF	AHTop Med	12/12/2021	Nil		A
903	S 3 NBRZ 19 Pine Brush SF	AHTop Med	12/12/2021	Nil		
904	S 3 NBRZ 19 Pine Brush SF	AHBasS mall	13/12/2021	Nil		
905	S 3 NBRZ 19 Pine Brush SF	AHBasS mall	13/12/2021	Nil	Squirrel Glider, Brushtail Possum	
906	S 3 NBRZ 19 Pine Brush SF	AHTop Med	12/12/2021	Nil		
907	S 3 NBRZ 19	AHTopS mall	12/12/2021	Nil		
908	S 3 NBRZ 19 Pine Brush SF	AHTopS mall	12/12/2021	Nil		
909	S 3 NBRZ 19 Pine Brush SF	AHBasS mall	12/12/2021	Nil	Squirrel Glider	
910	S 3 NBRZ 19 Pine Brush SF	AHTop Med	0/01/1900			
911	S 3 NBRZ 19 Pine Brush SF	AHTopS mall	13/12/2021	Nil		
912	S 3 NBRZ 19 Pine Brush SF	AHBasL arge	13/12/2021	Nil		
913	S 3 NBRZ 19 Pine Brush SF	AHBasS mall	13/12/2021	Nil		
915	S 3 NBRZ 4/5 Old Six Mile Lane	AHTop Med	12/12/2021	Nil		
916	S 3 NBRZ 4/5 Old Six Mile Lane	AHTopS mall	12/12/2021	Nil		

Number	Location	Type	Date monitored	Burrow scope (within hollow)	Camera (outside hollow)	Pest Species
917	S 3 NBRZ 4/5 Old Six Mile Lane	AHTop Med	12/12/2021	Nil		
918	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasLarge	12/12/2021	Nil	Nil	
919	S 3 NBRZ 4/5 Old Six Mile Lane	AHTopSmall	12/12/2021	Nil		
920	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasSmall	12/12/2021	Nil		
921	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasLarge	12/12/2021	Nil		
922	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasSmall	12/12/2021	Nil		
923	S 3 NBRZ 4/5	AHBasSmall				
924	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasSmall	12/12/2021	Nil		
925	S 3 NBRZ 4/5 Old Six Mile Lane	AHTopSmall	12/12/2021	Nil		
926	S 3 NBRZ 4/5 Old Six Mile Lane	AHBasSmall	12/12/2021	Nil		



Photo 12: Squirrel Gliders inspecting the HollowHog Homes.

4. Discussion

4.1 Performance Indicator 1: Boxes used by a wide variety of fauna species

Nest boxes are being used by a wide variety of fauna species. Seventeen vertebrate species were observed occupying nest boxes during the 2021 inspections and there have now been a total of 29 native vertebrate fauna species recorded occupying nest boxes since monitoring began in 2017. As reported in previous monitoring reports (ELA 2018 & ELA 2019) this represents a greater species diversity than reported for similar TfNSW nest box programs on the Pacific Highway upgrade. Similar programs include those immediately to the south at Sapphire to Woolgoolga (S2W), Woolgoolga to Halfway Creek (W2HC) and Halfway Creek to Glenugie (HC2G) (Sandpiper 2016a and 2016b and Ecosure 2017). The greater number of nest boxes, larger area and greater diversity of surrounding habitats than on any adjacent nest box projects is likely the reason for this species diversity.

Almost 70% of records in Autumn and in Spring were attributed to just four dominant mammal species (Common Brushtail Possum, Squirrel Glider*, Eastern Long-eared bat* and Gould's Wattle Bat). This result is similar to those reported on other nest box projects with a review of TfNSW nest box projects, finding that arboreal mammals (particularly Squirrel Gliders, Sugar Gliders, Common Brushtail Possums and Brush-tailed Phascogales) were the most successful species groups in terms of nest box uptake (Goldingay 2019).

The performance target of 50% of boxes being used or showing previous signs of use by native fauna was not achieved in autumn or spring 2021 with 26% and 25% of boxes used by native fauna respectively.

The overall rates of nest box usage by all species are below the range reported on similar nest box monitoring projects (such as S2W), where overall usage was reported at 51-58% (Sandpiper 2016a), W2HC where overall usage was reported at 30-56% (Sandpiper 2016b), and Cooperook where overall usage was reported at 65-74% (Sandpiper 2015), and Branxton 47-67% (Sandpiper 2015). However, is similar to the adjacent HC2G where overall usage was reported at 14-26% (Ecosure 2017).

The current rates of nest box usage are also substantially less than recorded in previous years monitoring events on this project Table 21:

- 2018 report: The overall rate of useage (i.e. sum of boxes occupied and those featuring evidence of use) in Autumn 2018 was 293 boxes (56%) of 519 monitored boxes and 324 (55%) of 591 monitored boxes in Spring 2018.
- 2019 report: The overall rate of useage (i.e. sum of boxes occupied and those featuring evidence of use) in Autumn 2019 was 273 of 516 boxes (53%) and 207 of 543 boxes (38%) in Spring 2019-20.
- The overall rate of useage (i.e. sum of boxes occupied and those featuring evidence of use in Autumn 2021 was 152 of 589 boxes (26%) and 194 of 761 boxes (25%) in Spring 2021.

Table 21: Comparison of overall rates of nest box useage from 2018-2021

Year	Autumn	Spring
2018	56%	55%
2019-20	53%	38%
2021	26%	25%

This may be due to a number of factors. One would expect to see high numbers of nest box utilisation from displaced fauna immediately following vegetation clearing and highway construction, followed by a drop in subsequent years as fauna numbers stabilise in their now reduced habitat area. Ongoing population level effects from the drought and fires in 2019 and 2020, ongoing impacts from habitat removal and fragmentation for the W2B project, the very short time frame between installation of Spring 2021 boxes prior to monitoring and many other ecological factors that affect wild animal populations may be influencing nest box usage.

4.2 Performance Indicator 2: Boxes occupied by target fauna species

In the majority of cases where nest box occupancy was recorded, nest boxes were occupied by non-target fauna species. Only 4 of the 24 threatened species targeted by the nest box program have been recorded using the boxes. This included Brush-tailed Phascogale and Squirrel Glider which were using both target and non-target boxes. As mentioned previously in this document some of the species targeted by the nest box program are unlikely to utilise nest boxes. At least four of the 13 threatened microbats listed as target threatened species are not known to use nest boxes as roosting habitat and a further three species use nest boxes predominantly when they are installed in subterranean locations (under bridges and in culverts) rather than in trees.

Thirteen (54%) of the 24 target threatened species are microbats whilst only 117 of the 847 installed boxes are microbat boxes (14%). Usage of nest boxes by threatened Large Forest Owls and birds in general is also typically low. The four species of Large Forest Owl listed in Table 1 comprise 16% of the 24 target threatened fauna whilst only 61 (7%) of the installed nest boxes are suitable for Forest Owls. The ability of the nest boxes to compensate for target threatened fauna species must be viewed with these limitations in mind.

Rates of nest box uptake by the species for which the box was designed were 4% and just below the target of $\geq 5\%$. Seven box types recorded occupancy by target species and these were:

- Glider front and rear entry boxes – Sugar and Squirrel Glider
- Possum / Large Glider boxes – Common Brushtail Possum, Short-eared Brushtail Possum, Squirrel Glider
- Microbat boxes (Single chamber, 2 chamber, 3 chamber and 4 chamber) – Eastern Long-eared Bat, Gould's Long-eared Bat, Nyctophilus sp., Southern Myotis and Gould's Wattle Bat

It is currently unclear as to the purpose of this performance target. While certain nest box designs may suit some target species and fauna groups more than others, provided a suitable number and diversity of fauna or threatened species are utilising the boxes provided, the target species or fauna group of a particular box is largely irrelevant. For example in the current study Squirrel/Sugar Glider nests and individuals were found in 12 different nest box designs including boxes designed for gliders. In this situation, the presence of a threatened Squirrel Glider in a non-target box counts against this performance indicator. It is recommended that this performance indicator is reconsidered in future monitoring reports.

4.3 Performance Indicator 3: Pest species

The performance indicator target of <15% pest species uptake was met. No exotic fauna species were recorded using nest boxes other than European bees.

Ants were the most common pest occupying nest boxes followed by termites and European bees.

During the current inspection, vertebrate fauna was not observed in boxes containing ants and it is assumed to be a deterrent to use of nest boxes by most vertebrate fauna. Termite damage was a problem in a number of timber boxes with 14 timber boxes destroyed by termites. The use of CYPLAS boxes may help to overcome this issue with no termite damage recorded for CYPLAS.

Where possible pest species are currently dealt with in situ by leaving the box lid open as a deterrent between monitoring inspections and clearing old nests / hives out. This practice seems to be effective with fauna returning to boxes following removal of pests.

4.4 Performance Indicator 4: Repair and Maintenance

The performance target for repair and maintenance was achieved with less than 10% of boxes requiring maintenance or repair. The nest boxes monitored in 2021 included 51 boxes which were damaged and required replacing, predominately due to fire but also timber boxes being destroyed by termites and damage from falling trees or branches during storms. Repair and maintenance are a necessary part of successful nest box program to ensure boxes continue to be effective for as long as possible.

4.5 Comparison of the performance of timber and CYPLAS nest boxes

Despite the smaller number of CYPLAS boxes, 70% of the total fauna species encountered have used been recorded using CYPLAS boxes and over half the recorded species have been recorded in both material types, including three of the four threatened species directly recorded in nest boxes to date. While a controlled study is needed to conclusively compare to two materials, controlling numbers of boxes, installation dates, height, aspect and location, both box materials clearly do provide suitable shelter for a large number of fauna species including a number of threatened species.

Occupancy results from 2019 and the current study appear to indicate a slightly increased use of CYPLAS boxes over the autumn period and a substantial (10%) decrease in occupancy in spring. This may be due to differences in thermal and ventilation properties between the two materials.

Anecdotal and unpublished evidence suggests that higher temperatures can be expected in CYPLAS boxes than in timber boxes of the same type, when directly exposed to the sun (ELA pers. Comm. 2018, Sandpiper 2016d). Goldingay (2015) conducted trials testing the temperature profiles and associated rates of uptake of paired nest boxes, and recommended nest boxes for non-flying mammals should be installed to minimise extreme temperatures. For this reason, the usage of CYPLAS boxes in Spring was expected to be lower than that in autumn, because of the likelihood of exposure to higher temperatures and associated detrimental effects on fauna. Condensation was observed on the interior of occupied CYPLAS boxes and humidity levels and differences in air flow may also play a role in the uptake of nest boxes. This is another area where further research could be undertaken. During 2021 installations boxes were orientated south, east and/or southeast to avoid the afternoon sun. Some boxes were orientated north or north east due to safety reasons during the installation. Western aspects were avoided where possible.

Repair and maintenance requirements for CYPLAS boxes have been lower to date than for timber boxes. Many more observations of ants and termites have been recorded in timber boxes, with termites destroying a number of timber boxes between 2019 and 2021. This resistance to termites is expected and is stated as one of the advantages of the composite plastic and cypress pine material. The CYPLAS is also reported to be more resistant to rot than traditional timber boxes. Future monitoring results may reveal the advantages of this material as timber boxes are expected to decay become chewed by fauna and termite eaten over time.

4.6 Hollowhog

Construction of Hollowhog in trees is a new approach compared to traditional nest boxes. Studies show Hollowhog to regulate temperatures more efficiently and are less conspicuous decreasing the chances of predator disturbance compared to traditional nest boxes (William, 2021). Recent studies have found a higher number of species occupying Hollowhog when compared to nest boxes (William, 2021).

Hollowhog were installed at the end of October 2021 and given the short time period between creation and inspection it is unsurprising that no fauna was recorded during inspections. Three species Squirrel Glider, Brushtail Possum and Sugar Glider were photographed with remote camera showing interest and likely attempting to enlarge the created hollows.

The installed hollows have a small entrance diameter (3.5 – 5cm) and are likely most suited to smaller fauna species. Future monitoring will evaluate these structures and whether they are likely to provide more permanent habitat for native fauna than traditional nest boxes.

5. Recommendations

This section provides recommendations for the nest box monitoring program.

Table 22 provides a summary of performance and proposed actions.

Results of the monitoring in 2021 have identified 51 boxes need to be replaced, primarily due to fire damage in 2019/20. Replacement of termite damaged boxes with CYPLAS boxes may reduce the number of boxes requiring maintenance or replacement. If installing Hollowhog, a range of hollow sizes should be considered where possible and practical.

Given a significant percentage of nest boxes are not occupied/utilised, and as such a high percentage of boxes are available for useage at current time it should be considered that additional or replacement boxes may not be necessary. This will be revised after the 2023 Autumn monitoring period after which a determination of whether additional nest box installations are required. .

Table 22: Performance indicator, target status and proposed corrective action

Performance indicator	Target	Status	Corrective action
1. Use of nest boxes by a range of fauna species	Boxes inhabited by any fauna species within four years. Overall rates of use >50%.	Not achieved in Autumn or Spring with 26% and 25% of boxes used by native fauna respectively.	Nil – revise at end of 2023 Autumn monitoring event and determine whether action is required (i.e. installation of replacement boxes). Several contributing factors may include; - Spring / Summer 2019-20 bushfires; - Very recent installation of replacement boxes relative to monitoring event in Spring 2021. - Reluctance for fauna to inhabit areas adjacent to M1 highway due to disturbance from noise & light pollution & edge effects.
2. Use of boxes by target species	≥5% occupancy of nest boxes by species for which the box was designed.	Not achieved. 4% boxes inhabited by species for which the box was designed during 2021. Four of 24 threatened species targeted by the nest box program were detected using boxes.	Review box design and placement for the 50 boxes due to be replaced to maximise chance of threatened species uptake.
3. Low rates of pest species usage	<15% of boxes	Achieved 10% Autumn and 11% Spring	Not applicable target achieved

Performance indicator	Target	Status	Corrective action
4. Reduced maintenance and repair requirements	<10% boxes requiring repair or maintenance	Achieved 81 boxes (9%) require repair or replacement. 51 boxes require replacement	Revise at end of 2023 Autumn monitoring event. If replacement boxes are to be installed consider replacing the 51 plus any additional lost/damaged boxes with CYPLAS boxes to prevent termite damage.

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Appendix A - Weather

Date	Min temp °C	Max temp °C	Rainfall (mm)	Wind direction	Max wind speed (km/hr)
18/04/2021	9.7	23.1	17.8	SSW	9
19/04/2021	9.4	24.8	0.2	NNE	20
20/04/2021	9.2	25.6	0	N	24
21/04/2021	8.3	27.8	0.2	SSE	30
22/04/2021	7.0	22.4	0	NNW	20
17/05/2021	2.8	20.4	0	S	24
18/05/2021	5.2	21.9	0	SSW	20
19/05/2021	5.5	22.8	0.2	SE	26
20/05/2021	6.9	23.5	0.2	NNE	19
24/05/2021	11.3	22.4	0	SSE	30
25/05/2021	12.4	22.5	0.8	SSE	20
16/11/2021	10.9	27.2	0	E	37
17/11/2021	14.7	24.2	0	E	37
18/11/2021	16.3	26.2	0	NNE	33
19/11/2021	13.8	29.5	0	NNE	33
22/11/2021	18.6	24.0	20.2	S	33
23/11/2021	18.5	26.7	0	SE	31
24/11/2021	17.8	26.7	0.4	NE	28
25/11/2021	21.0	25.8	8.0	NNE	31
26/11/2021	20.7	28.5	24.0	NE	37
28/11/2021	16.9	25.8	0	SSE	35
29/11/2021	17.2	25.2	0	ESE	26
01/12/2021	18.2	25.2	35.6	SSE	28
02/12/2021	17.1	29.7	2.0	SSE	48
03/12/2021	17.2	29.8	0.2	ESE	28
04/12/2021	16.7	31.0	0	SE	46
05/12/2021	17.8	24.7	7.8	SSE	44
06/12/2021	16.6	25.6	5.8	S	33
07/12/2021	17.9	28.9	6.0	SSE	35
08/12/2021	18.4	29.0	11.0	NE	31
09/12/2021	18.0	30.0	3.8	ESE	33
10/12/2021	17.6	31.0	19.4	WSW	28
12/12/2021	16.3	26.0	0	SSE	35

Date	Min temp °C	Max temp °C	Rainfall (mm)	Wind direction	Max wind speed (km/hr)
13/12/2021	15.3	27.1	0.2	SSE	33

Appendix B - W2B Sections 3 to 11 Nest Box Management Plan Addendum



W2B Sections 3 to 11 Nest Box Management Plan Addendum

Transport for New South Wales

DOCUMENT TRACKING

Project Name	W2B Sections 3 to 11 Nest Box Management Plan Addendum
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Abbreviations

Abbreviation	Description
BC Act	NSW <i>Biodiversity Conservation Act 2016</i>
ELA	Eco Logical Australia
EPBC	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
HBT	Hollow-bearing tree

Abbreviation	Description
HDF	Hollow dependent fauna
MCoA	Minister's Condition of Approval
NBMP	Nest Box Management Plan
NBRZ	Nest Box Replacement Zone
NP	National Park
NR	Nature Reserve
PC	Pacific Complete
SCA	State Conservation Area
TfNSW	Transport for New South Wales
W2B	Woolgoolga to Ballina

Executive Summary

Eco Logical Australia (ELA) has been engaged by Pacific Complete (PC) and Transport for NSW (TfNSW) to undertake Nest Box Installation and Monitoring for Sections 3 - 11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B). This includes supply, delivery, installation, monitoring and maintenance of 698 nest boxes of 22 different types along the 155 km Pacific Highway corridor between Woolgoolga and Ballina.

Nest Box Management Plans (NBMPs) were prepared that provided guidance on the number and type of nest boxes required to be installed and suggested potential receptor sites, known as Nest Box Replacement Zones (NBRZs) for the installation of nest boxes. The NBMPs combined estimated that 698 nest boxes were required to be installed on Sections 3-11 of the W2B project, with 70% of those to be installed prior to clearing of vegetation. The remaining 30% of nest boxes were to be installed post-clearing once a final tally of hollow bearing trees (HBTs) could be compiled from data collected during clearing supervision.

This addendum outlines the process and justification for the methodology used to calculate the 100% quota of nest boxes. Rather than following the formula set out in the NBMPs to determine the number of nest boxes required after clearing, the number of nest boxes required was calculated as follows:

Estimated boxes (Est boxes) / Estimated HBTs (Est HBTs) (both numbers taken from the NBMPs) X Number of actual hollow bearing trees (HBTs) cleared in each Section.

When the formula provided in the NBMPs was applied to Section 3 clearing data, it returned a result for the number of nest boxes required that far exceeded the number provided in the NBMP for Section 3 when an equivalent number of HBTs were removed. It was not practical to install more than twice as many nest boxes through Section 3 as had been estimated in the NBMP. Use of the above method also removed the need to rely on details regarding the number and size class of hollows cleared which was not always reported in the clearing data but was required if applying the formula provided in the NBMPs.

A total of 547 of the estimated 698 nest boxes (as identified in the NBMPs) were installed prior to clearing of vegetation for the W2B project, exceeding the target of 493 required to achieve 70% installation prior to vegetation clearance. Additional boxes were also installed prior to clearing as variations for works that were not able to be included in the assessment for the NBMPs, after an assessment of HBTs and hollow size classes to be removed in these areas was conducted. After applying the ratio of Est boxes : Est HBTs to the actual number of HBTs cleared (excluding HBTs cleared under variations), the combined total number of nest boxes remaining to be installed for the 100% install is 203. The single nest box required in Section 4 and Section 5 to fulfill the 100% quota will not be installed because the NBRZs are at capacity throughout these Sections. An additional 2 nest boxes are required to fulfil the 100% quota for the Avenue Road variation which was treated separately. Therefore, the number of nest boxes required to be installed is 204.

There are several guiding principles by which the 100% nest box quota will be allocated to nest box type and to the most suitable location within the W2B project. These principles are:

1. Only arboreal mammal nest box types or those that have been successfully used (bat boxes in certain locations) on the W2B project will be installed as part of the 100% quota allocation (ELA 2021).
2. Nest boxes will be installed such that clusters of three or more of the same box type are installed on three different trees present in each NBRZ and clusters of the same box type are separated by at least 200m.
3. Nest boxes will be installed at heights between 3 and 5 m, with the aim of being safely accessible from a ladder.
4. Nest boxes will be installed in NBRZs that are known to be inhabited by target species.
5. Nest boxes will be installed in NBRZs that can be safely accessed for monitoring and installation and that will not become over supplied with nest boxes.
6. Any nest boxes required to be purchased for the 100% quota will be constructed from Cyplas. The exception to this will be the 62 timber boxes remaining in stock which will all be installed on the W2B project.
7. Consideration should be given to the installation of artificial (chainsaw) hollows (where the safety distance requirements from the highway can be met) for a portion (approx. 10 %) of the 100% nest box quota, and that these be installed in areas where nest boxes are also available for the target species so that inferences on preferences can potentially be drawn.

Locations suitable as receptor sites for nest boxes predominantly include existing NBRZs within the project boundary that are not at capacity. Receptor sites have also been selected based on a number of other criteria including the presence of target threatened fauna identified during nest box monitoring inspections and access safety for nest box installation and future monitoring inspections.

There are also a number of land parcels that have been selected outside of the project boundary on land acquired by TfNSW as offset sites which will be managed and maintained for the purposes of conservation in perpetuity.

In addition to the nest boxes required for 100% quota, a total of 55 nest boxes have been damaged or lost through clearing, termites, tree fall, fire and theft on the W2B project since the nest boxes were installed. These nest boxes shall be replaced in the NBRZs from which they were originally installed to maintain the 100% nest box quota. A total of 259 nest boxes are therefore required to be installed to complete the 100% quota and account for replacement boxes.

The 204 nest boxes required for the 100% quota will comprise a mix of box types including 2 or 3 Chambered Bat Boxes, Antechinus, Brush-tailed Phascogale, Feathertail Glider, Glider Rear Entry and Possum / Large Glider (Table 1). A total of 23 boxes required for the 100% quota will be sourced from those in stock, with the remaining 181 to be newly purchased (Table 1). The 55 replacement boxes will comprise a mix of box types including 2 Chambered Bat Boxes, Antechinus, Barn Owl / Wood duck, Brush-tailed Phascogale, Cockatoo / Owl, Dollar Bird / Crimson Rosella, Galah, Glider Rear Entry, Kingfisher, Pardalote, Possum / Large Glider, Quoll and Small Parrot (Table 1). A total of 39 boxes required as replacement boxes will be sourced from stock with the remaining 16 boxes newly purchased (Table 1). Other than the 62 nest boxes remaining in stock which will be utilised as part of the

replacement box quota (where box types match or closely resemble the box type to be replaced) as well as the 100% box quota, any new boxes required to be purchased will be constructed from Cyplas or comprise an artificially created tree hollow (chainsaw hollow).

Table 1. Summary of nest box types to be sourced or created using artificial hollows to fulfil 100% quota and replacement boxes.

Nest box type	100% quota		Subtotal	Replacement boxes		Subtotal	Total
	New	In stock		New	In stock		
2 Chamber Bat	17	0	17	4	0	4	21
3 Chamber Bat	14	0	14	0	0	0	14
4 Chamber Bat	0	0	0	0	0	0	0
Antechinus	35	0	35	0	1	1	36
Barn Owl / Wood duck	0	0	0	2	0	2	2
Brush-tailed Phascogale	25	0	25	3	3	6	31
Cockatoo / Large Owl	0	1	1	0	7	7	8
Dollar Bird / Crimson Rosella	0	3	3	0	2	2	5
Feathertail Glider	26	0	26	0	0	0	26
Galah	0	2	2	0	2	2	4
Glider Rear Entry	51	0	51	6	0	6	57
Kingfisher	0	0	0	0	3	3	3
Pardalote	0	0	0	1	0	1	1
Possum / Large Glider	13	15	28	0	16	16	44
Spotted-tail Quoll	0	2	2	0	1	1	3
Small Parrot	0	0	0	0	4	4	4
Total	181	23	204	16	39	55	259

1. Nest Box Management Plans

Eco Logical Australia (ELA) has been engaged by Pacific Complete (PC) and Transport for New South Wales (TfNSW) to undertake Nest Box Installation and Monitoring for Sections 3-11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B) as per the specifications set out in the Nest Box Management Plans (NBMPs) for each Section (GeoLINK 2014a and 2014b, AECOM 2014, Biosis 2014, Melaleuca Group 2014 and Australian Museum Consulting 2014). This includes supply, delivery, installation, monitoring and maintenance of an estimated 698 nest boxes of 22 different types along the 155 km Pacific Highway corridor between Woolgoolga and Ballina. The primary objective of the NBMPs is to provide some compensation and alternative habitat provisions for hollow dependent fauna (HDF) that will be impacted by the removal of hollow-bearing trees (HBTs) cleared as part of the W2B project.

The W2B project is divided into Sections (3-11) that have been assessed and reported upon separately by a range of contractors for the NBMPs. The NBMPs provide details on the numbers and types of nest boxes required to be installed based upon the results of ground-based surveys of HBTs within the clearing footprint and in reference sites adjacent to the alignment. Surveys of HBTs estimated the number and size class of hollows contained within each HBT scheduled to be cleared. A formula was then applied to calculate the number of nest boxes required. The list of hollow size classes and knowledge of fauna known to occur in the area was used to provide the proportional allocation of nest box types within each Section.

Each Section of W2B has then been further divided into roughly 500m chainages, also referred to as Nest Box Replacement Zones (NBRZs). The NBRZs are smaller areas within each W2B Section that provide a practical organisational structure and suitable location for the installation of nest boxes. Nest boxes are required to be installed in NBRZs where the density of HBTs in the adjacent is less than 4 hollow-bearing trees (HBTs) per hectare.

The NBMPs combined estimate that 698 nest boxes are required to be installed on Sections 3-11 of the W2B project, with 70% of those to be installed prior to clearing of vegetation (Table 2). The remaining 30% of nest boxes are to be installed post-clearing once a final tally of hollows and HBTs has been compiled from data collected during clearing supervision. During the clearing process details of the actual number of HBTs removed were recorded. These details have been used to provide a more accurate figure for the total number and types of nest boxes required to compensate for clearance of HBTs across Sections 3-11 of the W2B project.

A total of 547 of the estimated 698 nest boxes (as identified in the NBMPs) were installed prior to clearing of vegetation for the W2B project, exceeding the target of 493 required to achieve 70% installation prior to vegetation clearance. There were also several variations to the NBMPs required as a result of updates and changes to the detailed design that occurred after the NBMPs had been prepared that accounted for additional nest box installation above the original 70% installation target of 493 nest boxes. Including variations there have been 664 nest boxes installed on the W2B project. The nest boxes associated with these changes were installed following an assessment of the number and size classes of HBTs to be removed.

This report summarises the methodology used to calculate the final quota of nest boxes representing the 100% installation figures, provides recommendations on the nest box types / artificial hollows

required to be installed and suitable locations for installation. This addendum outlines the process and justification for the methodology used to calculate the 100% quota of nest boxes.

Table 2. Summary of estimated number of nest boxes required per Section as reported in the NBMPs.

Section	NBMP #	70% install target	70% installed (NBMP only not including variations)*
3A	12	9	12
3	311	218	224
4	86	61	70
5	44	31	31
6	23	17	27
7	49	35	37
8 and 9	102	72	90
10 and 11	71	50	54
Total	698	493	547

*Excludes boxes installed as variations or under early works packages not covered by NBMPs

2. Target species and nest box program performance evaluation

A range of hollow-dependent threatened and protected fauna species are known to occur across Sections 3 – 11 of the W2B project (the subject site), including forest owls, woodland birds, microbats and arboreal mammals. The list of threatened hollow dependent species referred to as target species in each NBMP is slightly different for each Section because of changes in vegetation and proximity of each Section to existing populations of threatened species. Table 3 provides a combined list of 24 threatened HDF species known from records within 5km of the W2B alignment that were targeted in the NBMPs and / or listed as threatened under the *Biodiversity Conservation Act 2016* (BC Act) or *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) since the NBMPs were prepared. Nest box installation is one of many mitigation measures being implemented to minimise impacts to native fauna species from the W2B project and forms part of the Minister’s Conditions of Approval (MCoA) for the project.

Nest boxes are monitored twice per year in Autumn and Spring. Monitoring events during 2017, 2018 2019, and Autumn 2021 have been completed and monitoring events scheduled for Spring 2021 and 2023 are yet to be completed. A range of performance measures have been set up to evaluate whether the nest boxes are being used by a wide range of fauna species, and to determine whether target fauna species are inhabiting and breeding in boxes designed specifically for them. Performance measures also include an evaluation of the uptake of nest boxes by pest species and rates of repair and maintenance. Corrective actions are enacted where performance criteria are not being achieved.

When discussing nest box monitoring results, the following definitions apply:

- Evidence of use: a box contains signs that an animal has visited and used the nest box for shelter or breeding purposes. Signs of visitation by an animal include nests of various forms, scats / guano, feathers, shed skins, bones, eggs, egg shells, scratches on the sides of the nest box, chewing around the entrance hole, a depression in the sawdust provided as bedding material, and hair or fur.
- Occupancy: a nest box is inhabited by an animal during the visual inspection.
- Usage: Total of occupancy and evidence of use combined.

To date, nest box usage rates generally exceed 50% during each monitoring event, whilst occupancy rates are around 6% overall. Rates of pest species uptake and maintenance have remained below 10% for each monitoring event (ELA 2020b, ELA 2021). Occupancy rates by the species for which the nest box was made are highest and either approach or exceed 10% for nest box types catering to arboreal mammals and in some cases bat boxes (ELA 2020b, ELA 2021). Cyplas boxes have been reported to experience lower pest species uptake and reduced maintenance issues, with early trends indicating higher levels of usage than timber boxes (ELA 2020b, ELA 2021). Timber boxes however recorded a greater species diversity (ELA 2020b, ELA 2021). Nest boxes targeting bird species have recorded limited success (ELA 2020b, ELA 2021).

Table 3. Combined list of threatened hollow dependent fauna species and the target nest box type included in the NBMPs for Sections 3 – 11 of the W2B project.

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
<u>Aves</u>				
<i>Calyptorhynchus lathami</i>	Glossy Black-cockatoo	V		Cockatoo / Large Owl
<i>Climacteris picumnus</i>	Brown Treecreeper	V		Tree Creeper
<i>Glossopsitta pusilla</i>	Little Lorikeet	V		Small Parrot
<i>Ninox connivens</i>	Barking Owl	V		Cockatoo / Large Owl
<i>Ninox strenua</i>	Powerful Owl	V		Cockatoo / Large Owl
<i>Tyto novaehollandiae</i>	Masked Owl	V		Cockatoo / Large Owl
<i>Tyto tenebricosa</i>	Sooty Owl	V		Cockatoo / Large Owl
<u>Mammals</u>				
<i>Dasyurus maculatus</i>	Spotted-tail Quoll	V	E	Spotted-tail Quoll
<i>Petauroides volans</i>	Greater Glider		V	Possum / Large-Glider
<i>Petaurus australis</i>	Yellow-bellied Glider	V		Possum / Large-Glider
<i>Petaurus norfolcensis</i>	Squirrel Glider	V		Glider (front and rear entry)
<i>Phascogale tapoatafa</i>	Brush-tailed Phascogale	V		Phascogale

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
Microbats				
<i>Chalinolobus dwyeri</i>	Large-eared Pied Bat	V	V	Single, 2, 3 or 4 chambered microbat
<i>Chalinolobus nigrogriseus</i>	Hoary Wattled Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Falsistrellus tasmaniensis</i>	Eastern False Pipistrelle	V		Single, 2, 3 or 4 chambered microbat
<i>Kerivoula papuensis</i>	Golden-tipped Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Miniopterus australis</i>	Little Bent-winged Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Miniopterus schreibersii oceanensis</i>	Eastern Bent-winged Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Mormopterus beccarii</i>	Beccari's Free-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Mormopterus norfolkensis</i>	Eastern Free-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Myotis macropus</i>	Southern Myotis	V		Single, 2, 3 or 4 chambered microbat
<i>Nyctophilus bifax</i>	Eastern Long-eared Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
<i>Scoteanax rueppellii</i>	Greater Broad-nosed Bat	V		Single, 2, 3 or 4 chambered microbat

3. Formula used to estimate the number of nest boxes required

The number of nest boxes required to be installed in each Section as reported in the NBMPs was obtained using the data gathered from ground-based surveys of HBTs to be cleared. All NBMPs applied the same formula to estimate the number of nest boxes required in each 500 m chainage (NBRZ) as follows;

Number of nest boxes required = $A \times B \times 1.2$

Where,

A = Density of hollow bearing trees (HBT/ha) calculated using data outlined below

A = Number of hollow bearing trees within clearing footprint / Area of vegetation to be cleared (ha)

And,

B = Mean number of hollows per tree calculated using data outlined below

B = Number of hollows / Number of hollow bearing trees

And,

1.2 = 20% error factor to account for difficulties associated with identifying tree hollows from ground based survey in certain habitat types (e.g. dense lower and mid stratum).

In each case the final figure for the number of nest boxes required is rounded up to the nearest whole number. The NBMPs then determined which NBRZ's required nest box installation based upon the density of hollows in the surrounding landscape. Only those NBRZ's with an adjacent density of <4 HBT/ha were selected to receive nest boxes. Where the resultant ratio of hollows removed : nest boxes required did not approach 1:1, as per the Roads and Traffic Authority Biodiversity Guidelines (2011), nest box numbers were increased or decreased to better reflect this ratio.

4. Process for calculating 100% nest box quota

The number and size classes of HBTs cleared in each Section was then used as the basis for the final 100% quota to be calculated. The process for calculating the final 100% quota involved consolidating data from numerous sources for each Section that listed the following information:

- NBRZ
- Estimated number of HBTs (from NBMP)
- Estimated number of hollows (from NBMP)
- Estimated area of vegetation to be cleared (from NBMP)
- Estimated number of nest boxes required using formula (from NBMP)
- Number of nest boxes installed pre clearing (data held by ELA)
- Actual number of HBTs cleared (data provided by clearing contractors)
- Actual number of hollows cleared (data provided by clearing contractors)
- Actual area of vegetation cleared (data provided by PC and TfNSW)
- 100% quota of nest boxes required (calculated using formula applied to actual clearing data)

The difference between the number of boxes installed vs the figure for the 100% quota = Number of boxes remaining to be installed.

Data provided from the clearing inspections in each Section was not always complete and as a result there were some Sections where information on the actual number of hollows cleared was not provided.

When the formula provided in the NBMPs was applied to Section 3 clearing data, it returned a result for the number of nest boxes required that far exceeded the number provided in the NBMP for Section 3 when an equivalent number of HBTs were removed. It was not practical to install more than twice as many nest boxes through Section 3 as had been estimated in the NBMP. It was therefore not practical to use the formula to calculate the 100% quota and alternative methods were devised.

During investigations for alternative methods of calculation it was determined that the ratio of Estimated nest boxes required : Estimated HBTs to be cleared (from the NBMPs) provided a robust and consistent means for determining the number of nest boxes required when applied to the actual number of HBTs cleared and in the absence of data on the actual number of hollows cleared. Rather than following the formula set out in the NBMPs to determine the number of next boxes required after clearing, the number of next boxes required was therefore calculated by multiplying the ratio of Est boxes : Est HBTs (both numbers taken from the NBMPs) for each Section by the number of actual HBTs cleared. This method ensured consistency with the nest box numbers determined within the approved NBMPs and also ensured that nest boxes would not be oversupplied in the receiving environment, whilst still providing habitat for fauna displaced by clearing.

5. 100% nest box quota calculations

5.1 Section 3A and Section 3 100% calculations

A summary of the NBMP information (GeoLINK 2014a) and data obtained during clearing activities is presented in Table 4 below. Section 3 included early works nest box installations which were not included in the NBMP calculations. These early works were associated with design modifications and clearing required for ancillary facilities and road widening on Avenue Road. The 20 nest boxes installed to compensate for clearing associated with early works have been removed from the calculations as they were subject to a separate assessment process. Another two nest boxes are required to be installed to complete the 100% installation for the Avenue Road works, but these two boxes are not included in the calculations or final tally provided below. A total of 306 nest boxes (not including Avenue Road) were installed in Section 3A and Section 3 prior to vegetation clearance.

Based upon using the ratio of Est boxes : Est HBTs multiplied by the number of HBTs cleared, the 100% quota for Section 3 and Section 3A equates to 397 nest boxes (when rounded up to the nearest whole number), therefore 91 additional nest boxes are required to be installed for the 100% quota, and an additional two nest boxes are required for the Avenue road variation (Table 5).

Table 4. Section 3 and Section 3A 100% nest box calculation data

Chainages	NBRZ Required (Y/N)	Est NBMP	HBTs	Est Boxes Required NBMP	Nest	Actual HBTs Cleared	Actual Cleared NBRZs	HBT in Where Boxes Required	Nest Boxes Installed
33800-33900	Not in NBMP	0		0		0	0		0
34100-34600	N	0		0		0	0		0
34600-35100	N	0		0		5	0		0
35100-35600	N	3		4		6	6		12

Chainages	NBRZ Required (Y/N)	Est NBMP	HBTs	Est Boxes Required NBMP	Nest	Actual HBTs Cleared	Actual Cleared NBRZs Where Boxes Required	HBT in	Nest Boxes Installed
35600-36100	N	11		8		7	7		0
36100-36600	Y	6		8		16	16		7
36600-37100	N	0		0		14	0		1
37100-37600	N	0		0		14	0		0
37600-38100	Y	19		11		19	19		3
38100-38600	N	0		0		34	0		12
38600-39100	Y	6		8		25	25		6
39100-39600	N	0		0		3	0		28
39600-40100	Y	9		9		15	15		1
40100-40600	Y	6		3		7	7		0
40600-41100	N	0		0		24	0		0
41100-41600	Y	7		5		8	8		0
41600-42100	Y	5		0		6	6		0
42100-42600	N	0		0		0	0		0
42600-43100	N	0		0		0	0		0
43100-43600	N	0		0		0	0		0
43600-44100	N	0		0		2	0		0
44100-44600	Y	6		15		11	11		5
44600-45100	Y	12		0		18	18		10
45100-45600	Y	11		0		17	17		0
45600-46100	Y	16		8		24	24		15
46100-46600	Y	2		8		5	5		2
46600-47100	N	0		0		5	0		0
47100-47600	N	0		0		16	0		0
47600-48100	N	0		0		19	0		0
48100-48600	N	0		0		21	0		0
48600-49100	N	0		0		34	0		0
49100-49600	Y	9		8		10	10		6
49600-50100	N	0		0		7	0		0
50100-50600	N	0		0		35	0		0
50600-51100	N	0		0		40	0		0
51100-51600	Y	16		9		13	13		0
51600-52100	N	0		0		26	0		0
52100-52600	Y	11		20		15	15		2

Chainages	NBRZ Required (Y/N)	Est NBMP	HBTs	Est Boxes Required NBMP	Nest	Actual HBTs Cleared	Actual Cleared NBRZs Where Boxes Required	HBT in Where	Nest Boxes Installed
52600-53100	Y	29		0		18	18		20
53100-53600	N	0		0		23	0		0
53600-54100	N	0		0		12	0		0
54100-54600	Y	18		27		10	10		0
54600-55100	Y	20		0		24	24		19
55100-55600	N	0		0		58	0		0
55600-56100	N	0		0		60	0		0
56100-56600	N	0		0		64	0		0
56600-57100	Y	14		11		19	19		9
57100-57600	Y	12		22		14	14		14
57600-58100	Y	12		0		8	8		0
58100-58600	N	0		0		29	0		0
58600-59100	Y	20		19		31	31		14
59100-59600	N	0		0		43	0		0
59600-61100	N	0		0		26	0		0
60100-60600	N	0		0		30	0		0
60600-61100	N	0		0		27	0		0
61100-61600	N	0		0		17	0		0
61600-62100	Y	12		14		13	13		11
62100-62600	N	0		0		18	0		0
62600-63100	Y	7		26		9	9		7
63100-63600	Y	20		0		28	28		12
63600-64100	N	0		0		19	0		0
64100-64600	N	0		0		48	0		0
64600-65100	Y	19		14		41	41		11
65100-65600	Y	11		11		11	11		17
65600-66100	Y	10		10		15	15		0
66100-66600	N	0		0		25	0		0
66600-67100	Y	10		7		17	17		5
67100-67600	Y	20		16		26	26		14
67600-68100	N	0		0		1	0		19
68100-68800	Y	39		22		19	19		44
Total		428		323		1324	525		326

Table 5. Section 3A and Section 3 nest boxes required for 100% quota

Factor in calculation	Number value
Nest boxes installed	326
Section 3 nest boxes installed as variations / early works	20
Nest boxes installed for 100% calculations	306
HBTs cleared	525
Est boxes: Est HBTs	0.754672897
Nest boxes required (0.7547 x 525) for 100% quota	397
Additional nest boxes required	91

5.2 Section 4 & Section 5 100% calculations

A summary of the NBMP information (GeoLINK 2014b) and data obtained during clearing activities is presented in Table 6 below. Section 4 and Section 5 were subject to significant early works and detailed design reworking under the W2B project and as a result the NBMP did not capture all vegetation clearance required. Early works vegetation clearance that occurred in the zone of overlap between Section 3 and Section 4 at Tyndale, detailed design changes in the zone of overlap between Section 4 and Section 5 at Maclean cut and withheld permission from a landholder to undertake survey of impacted vegetation at the Iluka Rd interchange resulted in additional requirements for nest boxes. Clearing data for all of the variations was included in the clearing data provided. A total of 101 nest boxes were installed in Section 4 and Section 5 prior to vegetation clearance.

Based upon using the ratio of Est boxes : Est HBTs multiplied by the number of HBTs cleared, the 100% quota for Section 4 and Section 5 equates to 102 nest boxes, therefore one additional nest box is required to be installed (Table 7). The NBRZs throughout Section 4 and Section 5 already contain a high density of nest boxes and have limited remaining remnant vegetation within TfNSW tenure that could be used as receiver sites for additional nest boxes. Given this, it is advised that no further nest box installation occurs in Section 4 and Section 5. TfNSW have agreed that this outcome is an acceptable one for Section 4 and Section 5.

Table 6. Section 4 and Section 5 100% nest box calculation data

Chainages	NBRZ Required (Y/N)	Est NBMP	HBTs	Est Boxes Required NBMP	Nest HBTs Cleared	Actual HBTs Cleared	Actual Cleared NBRZs Boxes Required	HBTs in Where	Nest Installed	Boxes
68800-69500	Y	18	36	12	12	12	15			
69500-75500	N	0	0	0	0	0	0			
75500-76900	Y	40	50	51	51	51	52			
76900-79300	N	0	0	12	0	0	0			
79300-80050	Y	7	6	0	0	0	3			
80050-82000	N	0	0	5	0	0	0			
82000-89400	N	0	0	30	0	0	0			
89400-89600	Y	2	3	2	2	2	6			
95300-95800	Y	17*	35	1	1	1	25			
Total		84	130	113	66	66	101			

*Figure estimated from information reported in NBMP as the area was unable to be accessed for survey due to landholder restrictions.

Table 7. Section 4 and Section 5 nest boxes required for 100% quota

Factor in calculation	Number value
Nest boxes installed	101
HBTs cleared	66
Est boxes / Est HBTs	1.547619048
Nest boxes required (1.5476 x 66) for 100% quota	102
Additional nest boxes required	1

5.3 Section 6 100% calculations

A summary of the NBMP information (AECOM 2014) and data obtained during clearing activities is presented in Table 8 below. Section 6 was subject to additional works under the W2B project associated with the construction of an ancillary facility which required installation of nest boxes because of impacts to HBTs. The 6 nest boxes installed to compensate for impacts associated with this variation (the 6 boxes accounted for over the 100% impact requirements) have been removed from the calculations as they were subject to a separate assessment process. There are no further nest boxes required to be installed as part of the ancillary facility variation. A total of 29 nest boxes were installed in Section 6 prior to vegetation clearance.

Based upon using the ratio of Est boxes : Est HBTs multiplied by the number of HBTs cleared, the 100% quota for Section 6 equates to 31 nest boxes (when rounded up to the nearest whole number), therefore two additional nest boxes are required to be installed (Table 9).

Table 8. Section 6 100% nest box calculation data

Chainages	NBRZ Required (Y/N)	Est NBMP	HBTs	Est Boxes Required NBMP	Nest Actual Cleared	HBTs Actual Cleared	HBTs in Where Boxes Required	Nest Installed	Boxes
96500-98500	Y	2	2	2	14	14	2		
98500-100500	Y	8	3	3	6	6	5		
100500-102500	Y	7	4	4	3	3	10		
102500-104500	Y	27	6	6	25	25	4		
104500-105500	Y	21	8	8	0	0	6		
105500-111200	Not in NBMP	0	0	0	37	0	8		
Total		65	23	23	85	48	35		

Table 9. Section 6 nest boxes required for 100% quota

Factor in calculation	Number value
Nest boxes installed	35
Section 6 ancillary facility nest boxes installed as variation	6
Nest boxes installed for 100% calculation	29
HBTs cleared	85
Est boxes: Est HBTs	0.353846154
Nest boxes required for 100% (0.3538 x 85)	31
Additional boxes required	2

5.4 Section 7, Section 8 and Section 9 100% calculations

A summary of the NBMP information (Biosis 2014, Melaleuca Group 2014) and data obtained during clearing activities is presented in Table 10 below. A total of 127 nest boxes were installed in Section 7, Section 8 and Section 9 prior to vegetation clearance.

Based upon using the ratio of Est boxes : Est HBTs multiplied by the number of HBTs cleared, the 100% quota for Section 7, Section 8 and Section 9 equates to 183 nest boxes, therefore 57 additional nest boxes are required to be installed (Table 11).

Table 10. Section 7, Section 8 and Section 9 100% nest box calculation data

Chainages	NBRZ Required (Y/N)	Est HBTs NBMP	Est Nest Boxes Required NBMP	Actual HBTs Cleared	Actual HBT Cleared in NBRZs Where Boxes Required	Nest Boxes Installed
111000-111500	Y	2	2	2	2	1
111500-112000	N	0	0	12	0	0
112000-112500	N	0	0	28	0	0
112500-113000	N	0	0	22	0	0
113000-113500	N	0	0	21	0	0
113500-114000	N	0	0	40	0	0
114000-114500	N	0	0	10	0	0
114500-115000	N	0	0	0	0	0
115000-115500	N	0	0	0	0	0

Chainages	NBRZ Required (Y/N)	Est HBTs NBMP	Est Nest Boxes Required NBMP	Actual HBTs Cleared	Actual HBT Cleared in NBRZs Where Boxes Required	Nest Boxes Installed
115500-116000	Y	15	8	15	15	10
116000-116500	N	0	0	24	0	0
116500-117000	N	0	0	56	0	0
117000-117500	N	0	0	47	0	0
117500-118000	N	0	0	50	0	0
118000-118500	N	0	0	37	0	0
118500-119000	N	0	0	45	0	0
119000-119500	N	0	0	39	0	0
119500-120000	N	0	0	25	0	0
120000-120500	Y	19	7	20	20	5
120500-121000	Y	5	1	16	16	2
121000-121500	Y	8	3	12	12	2
121500-122000	Not in NBMP	0	0	6	0	0
122000-122500	Y	4	3	10	10	2
122500-123000	Y	11	5	10	10	5
123000-123500	Y	2	1	23	23	0
123500-124000	N	0	0	27	0	0
124000-124500	Y	17	4	24	24	4
124500-125000	N	0	0	19	0	0
125000-125500	Y	6	3	19	19	3

Chainages	NBRZ Required (Y/N)	Est HBTs NBMP	Est Nest Boxes Required NBMP	Actual HBTs Cleared	Actual HBT Cleared in NBRZs Where Boxes Required	Nest Boxes Installed
125500-126000	Y	5	2	19	19	2
126000-126500	N	0	0	8	0	0
126500-127150	N	0	0	10	0	0
127150-127600	Y	2	5	8	8	5
127600-129500	N	0	0	87	0	0
129500-130150	Y	13	10	12	12	7
130150-134650	N	0	0	72	0	0
134650-134900	Y	35	71	1	1	67
134900-136600	N	0	0	11	0	0
136600-136750	Y	3	12	4	4	8
136750-137600	N	0	0	14	0	0
137600-138200	N	0	0	2	0	0
138200-138950	Y	3	4	0	0	4
138950-145000	N	0	0	75	0	0
Total		150	141	982	195	127

Table 11. Section 7, Section 8 and Section 9 nest boxes required for 100% quota.

Factor in calculation	Number value
Nest boxes installed	127
HBTs cleared	195
Est boxes: Est HBTs	0.94
Nest boxes required (0.94 x 195)	184
Additional boxes required	57

5.5 Section 10 and Section 11 100% calculations

A summary of the NBMP information (Australian Museum Consulting 2014) and data obtained during clearing activities is presented in Table 12 below. There were some early works that occurred in Section 11 which required vegetation clearance and removal of HBTs that were not accounted for in the NBMP. The 14 nest boxes installed to compensate for clearing associated with these early works (14 boxes accounted for 100% of impact to HBT’s) have been removed from the calculations as they were subject to a separate assessment process, and no further nest boxes are required to be installed to offset the impact of this clearing. A total of 52 nest boxes were installed in Section 10 and Section 11 prior to vegetation clearance (Table 12).

Based upon using the ratio of Est boxes : Est HBTs multiplied by the number of HBTs cleared, the 100% quota for Section 10 and Section 11 equates to 104 nest boxes, therefore 52 additional nest boxes are required to be installed (Table 13).

Table 12. Section 10 and Section 11 100% nest box calculation data.

Chainages	NBRZ Required (Y/N)	Est NBMP	Est HBTs	Est Nest Boxes	Actual HBTs Cleared	Actual HBT Cleared in NBRZ Where Boxes	Nest Boxes Installed
145000-145500	N	0	0		0	0	0
145500-146000	N	0	0		0	0	0
146000-146500	Y	11	7		30	30	6
146500-147000	N	0	0		20	0	0
147000-147500	Y	5	3		2	2	1
147500-148000	Y	6	3		10	10	3
148000-148500	Y	3	1		4	4	1
148500-149000	Y	1	1		6	6	1
14900-149500	N	0	0		0	0	0
149500-150000	Y	19	15		23	23	0
150000-150500	Y	6	5		16	16	9
150500-151000	N	0	0		7	0	0
151000-151500	N	0	0		0	0	0

Chainages	NBRZ Required (Y/N)	Est HBTs NBMP	Est Nest Boxes Required NBMP	Actual HBTs Cleared	Actual HBT Where NBRZ Required	Cleared in Boxes	Nest Boxes Installed
151500-152000	N	0	0	0	0		0
152000-152500	N	0	0	4	4		0
152500-153000	N	0	0	7	7		0
153000-153500	N	0	0	0	0		0
153500-154000	N	0	0	0	0		0
154000-154500	N	0	0	0	0		0
154500-155000	N	0	0	2	0		0
155000-155500	N	0	0	0	0		0
155500-156000	N	0	0	9	0		0
156000-156500	N	0	0	0	0		0
156500-157000	N	0	0	3	0		0
157000-157500	N	0	0	5	0		0
157500-158000	N	0	0	6	0		0
158000-158500	N	0	0	7	0		0
158500-159000	Y	17	10	6	6		3
159000-159500	Y	3	3	3	3		14
159500-160000	Y	3	5	3	3		0
160000-160500	Y	1	3	1	1		0
160500-161000	Y	1	2	1	1		0
161000-161500	N	0	0	0	0		0

Chainages	NBRZ Required (Y/N)	Est HBTs NBMP	Est Nest Boxes Required NBMP	Actual HBTs Cleared	Actual HBT Where Boxes Installed	HBT Cleared in Boxes	Nest Boxes Installed
161500-162000	N	0	0	0	0		0
162000-162500	Y	1	3	1	1		3
162500-163000	Y	7	6	7	7		7
163000-163500	N	0	0	0	0		0
163500-164000	N	0	0	0	0		0
164000-164500	N	0	0	0	0		0
164500-165000	Y	1	4	0	0		4
Totals		85	71	183	124		52

Table 13. Section 10 and Section 11 nest boxes required for 100% quota.

Factor in calculation	Number value
Nest boxes installed	52
HBTs cleared	124
Est boxes: Est HBTs	0.835294118
Nest boxes required (0.8353 x 124) for 100% quota	104
Additional nest boxes required	52

5.6 Summary of 100% Nest box quota

The combined total number of nest boxes required to be installed as part of the 100% quota under the NBMPs is 203 (Table 14). The number of nest boxes proposed to be installed is 204 and includes two boxes required to be installed for the Avenue road variation in Section 3 (Table 14). The single nest box required in Section 4 and Section 5 will not be installed because the NBRZs are at capacity throughout these Sections.

Table 14. Combined total number of nest boxes required to fulfil 100% quota

Section	Number of nest boxes required to fulfil 100% quota	Number of nest boxes to be installed	Comments
3	91	93	Includes 2 boxes for Avenue Rd variation
4 and 5	1	0	Existing NBRZ at capacity
6	2	2	

Section	Number of nest boxes required to fulfil 100% quota	Number of nest boxes to be installed	Comments
7, 8 and 9	57	57	
10 and 11	52	52	
Total	203	204	

6. Factors contributing to allocation of nest boxes

In determining the proportional allocation of nest boxes to nest box types and NBRZs, a number of factors must be considered. In formulating the NBMPs, once the figure for the number of nest boxes required had been calculated, it was the list of species known to occur within the Section and the proportional allocation of hollow size classes within each Section that determined how many nest boxes of each nest box type were assigned to be installed. For the 100% quota allocation, this method of nest box assignment has been revised to account for significant findings from the monitoring results and the recommendations from recent reviews of nest box projects reported in the scientific literature as outlined in detail in Section 6.1 and 6.2 below.

6.1 Monitoring results

Nest box monitoring results gathered over 2017, 2018 and 2019 have shown that five (mammal) species of the 14 vertebrate species recorded using nest boxes account for the majority of records of occupancy and overall usage (ELA 2020, ELA 2021). These five mammal species are; *Nyctophilus gouldi* (Gould's Long-eared Bat), *Petaurus breviceps* (Sugar Glider), *Trichosurus vulpecula* (Common Brushtail Possum) and two target threatened species; *Nyctophilus bifax* (Eastern Long-eared Bat) and *Petaurus norfolcensis* (Squirrel Glider). These figures are the combined results across all nest box types. Several mammal species were recorded breeding in nest boxes (including the Squirrel Glider) indicating that nest boxes are also being used for key lifecycle functions and contributing to the reproductive success of these mammal species.

This result is similar to those reported on other nest box projects, with arboreal mammals being the most commonly encountered species using a range of nest box types (Sandpiper 2016a and 2016b and Ecosure 2017). It also aligns with the findings of a review of nest box projects commissioned by TfNSW, which similarly found that arboreal mammals (particularly Squirrel Gliders, Sugar Gliders, Common Brushtail Possums and Brush-tailed Phascogales) were the most successful species groups in terms of nest box uptake (Goldingay 2019).

Although the performance indicator targets for general occupancy and overall usage of nest boxes (all nest box types combined) have largely been met during the monitoring period, as have targets for pest species uptake and maintenance requirements; the performance indicator target for occupancy of a nest box by the species for which a nest box was designed (>10%) has not been attained. Based upon the literature, it has been argued that the target of 10% occupancy is too high for most box types other than arboreal mammals. There is a lack of documented evidence in the scientific literature for occupancy rates of many of the avian nest box types installed and little evidence that nest boxes are used by a range of bird species on a regular basis.

Early monitoring results show a trend for greater overall usage rates of Cyplas boxes by native fauna than for timber boxes (ELA 2020, ELA 2021). Cyplas boxes performed better than timber boxes, in relation to lower pest species uptake and levels of maintenance and repair (ELA 2020, ELA 2021). However, the diversity of fauna species using Cyplas boxes was lower than for timber boxes. Fifteen (65%) of the 23 vertebrate fauna species so far recorded in nest boxes on the W2B project since monitoring began in 2017 have been recorded in Cyplas boxes during monitoring, in comparison to 21 (91%) of the 23 species recorded in timber boxes (ELA 2021).

6.2 Literature review

A recent review of literature published on nest box projects completed in the last 10 years in Australia was conducted by Goldingay (2019) for TfNSW. Several important points regarding the use of nest boxes were highlighted and are summarised below.

6.2.1 Nest box types

Goldingay (2019) found that small gliders (Sugar Glider and Squirrel Glider) were the most successful users of nest boxes, found in 63% of small glider boxes as well as 21-33% of three other nest box types. Similarly, Brush-tailed Possums were found in 26% of possum boxes and in 23-32% of three other box types. Squirrel Gliders were the most frequently encountered threatened species detected in nest boxes (Goldingay 2019). Other threatened species detected in nest boxes were *Phascogale tapoatafa* (Brush-tailed Phascogale), *Petaurus volans* (Greater Glider) and *P. australis* (Yellow-bellied Glider). The non-flying mammals are the fauna group most likely to be affected by clearing of vegetation for road projects. Goldingay (2019) found enough evidence to support the continued installation of nest boxes for arboreal mammals displaced during clearing.

A single nest box is unlikely to serve the year round needs of any given animal and is likely to be used less often than a cluster of the same type of boxes. Goldingay (2019) has highlighted the need for several boxes of each type to be installed at a receptor site, in order to allow for periodic nest box switching to occur. Switching assists in parasite control and predator avoidance. In addition to this, clusters of boxes for single species should be spaced greater than 200m apart to cater to different individuals and social groups (Goldingay 2019).

Goldingay (2019) found that only a small number of boxes were used by birds despite a large number of boxes of a range of designs having been installed for birds in projects that were subject to review. Infrequent use of nest boxes by birds has been reported in other nest box programs associated with Pacific Highway upgrades (Sandpiper 2013 and 2015) and even in forest landscapes (e.g. Lindenmayer et al. 2009). It is likely that any birds residing in tree hollows in the cleared road footprint would find suitable hollows elsewhere given the ability for birds to move moderate to large distances relative to the amount of habitat lost through vegetation clearance for the W2NB project on a daily basis (Goldingay 2019). Unless there is a need to provide compensatory habitat for a specific population of a threatened bird species impacted by the W2B project there is little merit in installing bird boxes.

Goldingay (2019) found that 12% of bat boxes were used across the nest box projects being reviewed, however, the Glenugie Highway Upgrade project, abutting the southern end of the W2B project recorded very high usage rates of bat boxes with 46% of boxes used. Literature cited in Goldingay (2019) reported high variability in bat box use across different studies. Goldingay (2019) highlighted the landscape scale over which bats operate and suggested that the local availability of other roosting

habitat would influence bat box use. It was reported that more study is required on the roosting ecology of bats as well as on the circumstances that affect uptake of bat boxes. Goldingay (2019) suggests investigations on the roosting ecology of bat be undertaken in relation to new road projects and recommended the installation of bat boxes only in situations associated with bridge and culvert structures targeting the threatened *Myotis macropus* (Southern Myotis).

Despite these findings on the uncertainty surrounding bat box use, there has been successful uptake of bat boxes in several locations on the W2B project, including the use of bat boxes by the threatened Eastern Long-eared Bat. Given these monitoring results, the inclusion of bat boxes into the 100% quota is warranted and it is proposed that a number of bat boxes are installed as part of the 100% quota at selected locations.

6.2.2 Nest box design

There is enormous variability in the design and dimensions of nest boxes targeting the same species. The entrance diameter of a nest box is the key to which species can inhabit the nest box (Goldingay 2019). As a result of this and the findings of Goldingay (2019) discussed above; only three different nest box designs for arboreal mammals should be deployed on new road projects in future; a rear entry feathertail glider box (2.5 cm diameter entrance), a rear entry small glider box (4.5 cm entrance) and a possum box (10 cm entrance). Installation of nest boxes that fit within these categories will allow for uptake by a range of arboreal mammals known to use nest boxes and will allow comparisons to be made more easily between projects.

Goldingay (2019) considers the construction of artificial hollows by cutting them directly into the tree using a chainsaw as an emerging technique that warrants further investigation. There have been few studies to date however the data suggests that chainsaw hollows have been successful in attracting a diversity of species and that the temperature profiles are more stable than those offered by nest boxes (Ruegger 2017 and Griffiths et al 2018). A recent trial of the technique using 51 chainsaw hollows of three types (bats and gliders being the main target species) returned encouraging results. Ten hollows were monitored using remote cameras and 60% attracted interest from five fauna species (including two of the target threatened species; Brush-tailed Phascogale and Squirrel Glider), with repeat visits to the tree recorded over numerous days within the first 8 weeks of installation (ELA 2020a). Goldingay recommends trials are instigated to investigate the potential role that chainsaw hollows may play in future TfNSW mitigation programs, particularly for species that rarely if ever use nest boxes.

6.2.3 Nest box installation

Research has shown that nest boxes are more likely to be inhabited when they are placed in areas of contiguous habitat, rather than separated by cleared areas (Lindenmayer et al. 2016). In addition, there are several published studies linking proximity to roads and edges to decreased survival (McCall et al 2010), decreased abundance, presence and activity (Brearley et al 2010 and Francis et al 2015) and increased stress levels (Brearley et al 2010) in Squirrel Glider populations. Installing nest boxes in areas of contiguous habitat and at maximal distances from habitat edges is recommended.

The height at which nest boxes are installed plays a major factor in accessing nest boxes for monitoring / maintenance purposes and contributes to the costs involved. There is published data from a range of projects successful in attracting *Acrobates pygmaeus* (Feathertail Gliders), Squirrel Gliders, Sugar Gliders and Brush-tailed Phascogales to nest boxes at heights of 3 m (Goldingay 2019). With regards to nest

boxes for arboreal mammals, there is no requirement to install boxes any higher than 3 – 5 m, within a height range accessible from a ladder in line with a recommendation made by Goldingay (2019) in his review.

6.3 Guiding principles for allocation of 100% Nest box quota

The above descriptions provide several guiding principles by which the 100% nest box quota will be allocated to nest box type and to the most suitable location within the W2B project. These principles are:

1. Only arboreal mammal nest box types or those that have been successfully used (bat boxes in certain locations) on the W2B project will be installed as part of the 100% quota allocation (ELA 2021).
2. Nest boxes will be installed such that clusters of three or more of the same box type are installed on three different trees present in each NBRZ and clusters of the same box type are separated by at least 200m.
3. Nest boxes will be installed at heights between 3 and 5 m, with the aim of being safely accessible from a ladder.
4. Where possible, nest boxes will be installed in NBRZs that are known to be inhabited by target species
5. Nest boxes will be installed in NBRZs that can be safely accessed for monitoring and installation and that will not become over supplied with nest boxes.
6. Any nest boxes required to be purchased for the 100% quota will be constructed from Cyplas. The exception to this will be the 62 timber boxes remaining in stock which will all be installed on the W2B project.
7. Consideration should be given to the installation of artificial (chainsaw) hollows (where the safety distance requirements from the highway can be met) for a portion (approx. 10%) of the 100% nest box quota, and that these be installed in areas where nest boxes are also available for the target species so that inferences on preferences can potentially be drawn.

7. Replacement boxes

A total of 55 nest boxes have been damaged or lost through clearing, termites, tree fall, fire and theft on the W2B project since the nest boxes were installed (Table 15). These nest boxes must be replaced in the NBRZs from which they were originally installed to maintain the 100% nest box quota. ELA has a number of nest boxes in stock from the initial purchase which will be used to fulfil the requirements for replacement boxes where appropriate. Some departure between the nest box types requiring replacement and those installed from stock will be permitted because there are similarities between entrance sizes and general box dimensions between several nest box types. An alternative nest box type will only be provided from stock if it falls within the same entrance size class and general nest box dimensions as the box requiring replacement. Once these criteria have been applied, 39 of the 55 boxes requiring replacement can be accounted for using nest boxes held in stock by ELA (Table 15). There will

be 16 nest boxes purchased to account for replacement boxes that could not be matched to nest boxes held in stock by ELA (Table 15).

1 Table 15. Details of replacement nest boxes required for Sections 3 to 11 of the W2B project

Section	Location	Reason for replacement	for	Box Type	Material	Replacement box type	Source	Material	Comments
3	Zone 15	Replace cleared	-	2 Chamber Bat	Timber	2 Chamber Bat	New purchase	Cyplas	Recommend Feathertail Glider, Single or Double Chambered Bat box
3	Zone 12	Replace cleared	-	3 Chamber Bat	Cyplas	2 Chamber Bat	New purchase	Cyplas	Recommend Feathertail Glider, Single or Double Chambered Bat box
3	Zone 22.1	Replace termites	-	3 Chamber Bat	Timber	4 Chamber Bat	Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree
3	Zone 26 Centre	Replace - tree fall damage	-	4 Chamber Bat	Timber	4 Chamber Bat	Stock	Timber	
3	Zone 12	Replace cleared	-	Barn Owl / Wood duck	Timber	Galah	Stock	Timber	Entrance size similar between nest box types, volume of replacement box is smaller than original nest box
3	Zone 20	Replace termites	-	Barn Owl / Wood duck	Timber	Galah	Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree. Entrance size similar between nest box types, volume of replacement box is smaller than original nest box
3	Zone 19 Centre	Replace termites	-	Cockatoo/Large Owl	Timber	Cockatoo/Large Owl	Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree
3	Zone 22.1	Replace termites	-	Cockatoo/Large Owl	Timber	Cockatoo/Large Owl	Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree
3	Zone 26	Replace cleared	-	Cockatoo/Large Owl	Timber	Cockatoo/Large Owl	Stock	Timber	
3	Zone 25 South	Replace - tree fall damage	-	Glider Entry	Front Timber	Kingfisher	Stock	Timber	Entrance sizes and box dimensions very similar, Sugar and Squirrel Glider recorded in Kingfisher nest boxes on W2B project
3	Zone 9 South	Replace cleared	-	Glider Entry	Front Timber	Kingfisher	Stock	Timber	Entrance sizes and box dimensions very similar, Sugar and Squirrel Glider recorded in Kingfisher nest boxes on W2B project

Section	Location	Reason for replacement	Box Type	Material	Replacement box type	Source	Material	Comments		
3	Zone 26	Replace cleared	- Glider Entry	Rear	Timber	Glider Entry	Rear	New purchase	Cyplas	
3	Zone 26	Replace cleared	- Glider Entry	Rear	Timber	Glider Entry	Rear	New purchase	Cyplas	
3	Zone 4	Replace cleared	- Glider Entry	Rear	Timber	Glider Entry	Rear	New purchase	Cyplas	
3	Zone 25 South	Replace cleared	- Possum/ Glider	Large	Timber	Possum/ Glider	Large	Stock	Timber	
4	Zone 1 Tyndale	Replace cleared	- Barn Owl / Wood duck		Timber	Barn Owl / Wood duck		New purchase	Cyplas	
4	Zone Shark Ck E	Replace European bees	- Cockatoo/ Large Owl		Timber	Cockatoo/ Large Owl		Stock	Timber	
4	Zone Shark Ck E	Replace cleared	- Glider Entry	Front	Timber	Glider Entry	Rear	New purchase	Cyplas	
4	Zone 1 Tyndale	Replace cleared	- Unknown		Timber	Possum/ Glider	Large	Stock	Timber	Brush-tailed Possums and Gliders recorded in Zone 4 and adjacent Zone 26 justifies box type
4	Zone 1 Tyndale	Replace cleared	- Unknown		Timber	Possum/ Glider	Large	Stock	Timber	Brush-tailed Possums and Gliders recorded in Zone 4 and adjacent Zone 26 justifies box type
4	Zone 1 Tyndale	Replace cleared	- Unknown		Timber	Possum/ Glider	Large	Stock	Timber	Brush-tailed Possums and Gliders recorded in Zone 4 and adjacent Zone 26 justifies box type
4	Zone 1 Tyndale	Replace cleared	- Unknown		Timber	Antechinus		Stock	Timber	Antechinus recorded in Section 3 adjacent, Small gliders and Antechinus have been recorded in Antechinus boxes in Section 3, justifies box type
4	Zone Shark Ck E	Replace cleared	- Unknown		Timber	Possum/ Glider	Large	Stock	Timber	Brush-tailed Possums and Gliders recorded from this NBRZ
5	Zone 5 Illuka Rd	Replace termites	- 4 Chamber Bat		Timber	4 Chamber Bat		Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree

Section	Location	Reason for replacement	Box Type	Material	Replacement box type	Source	Material	Comments
6	Zone 2.1	Replace - fire	Barn Owl / Wood duck	Cyplas	Barn Owl / Wood duck	New purchase	Cyplas	
6	Zone 3.1	Replace - fire	Cockatoo/Large Owl	Cyplas	Cockatoo/Large Owl	Stock	Timber	
6	Zone 5d Devils Pulpit	Replace - fire	Cockatoo/Large Owl	Timber	Cockatoo/Large Owl	Stock	Timber	
6	Zone 2.1	Replace - fire	Possum/ Large Glider	Cyplas	Possum/ Large Glider	Stock	Timber	
6	Zone 3.1	Replace - fire	Possum/ Large Glider	Cyplas	Possum/ Large Glider	Stock	Timber	
6	Zone 3.1	Replace - fire	Possum/ Large Glider	Cyplas	Possum/ Large Glider	Stock	Timber	
6	Zone 3.2 McMahons	Replace - fire	Possum/ Large Glider	Cyplas	Possum/ Large Glider	Stock	Timber	
7	Zone 19/20	Replace - fire	Brush-tailed Phascogale	Timber	Brush-tailed Phascogale	New purchase	Cyplas	
7	Zone 24	Replace - fire	Brush-tailed Phascogale	Timber	Brush-tailed Phascogale	New purchase	Cyplas	
7	Zone 10	Replace - fire	Cockatoo/Large Owl	Timber	Cockatoo/Large Owl	Stock	Cyplas	
7	Zone 1	Replace - fire	Dollar Bird/Crimson Rosella	Timber	Dollar Bird/Crimson Rosella	Stock	Timber	Entrance size for Dollar Bird slightly larger than Tree Creeper but otherwise box dimensions similar
7	Zone 27	Replace - fire	Dollar Bird/Crimson Rosella	Timber	Dollar Bird/Crimson Rosella	Stock	Timber	Entrance size for Dollar Bird slightly larger than Tree Creeper but otherwise box dimensions similar

Section	Location	Reason for replacement	Box Type	Material	Replacement box type	Source	Material	Comments		
7	Zone 19/20	Replace - cleared	Glider Entry	Rear	Cyplas	Small Parrot	Stock	Cyplas	Entrance sizes and box dimensions very similar, Sugar and Squirrel Glider recorded in Small Parrot nest boxes	
7	Zone 19/20	Replace - fire	Glider Entry	Rear	Timber	Glider Entry	Rear	New purchase	Cyplas	
7	Zone 24	Replace - native bee hive	Glider Entry	Rear	Timber	Glider Entry	Rear	New purchase	Cyplas	
7	Zone 10	Replace - fire	Possum/ Glider	Large	Timber	Possum/ Glider	Large	Stock	Timber	
7	Zone 10	Replace - fire	Possum/ Glider	Large	Timber	Possum/ Glider	Large	Stock	Timber	
7	Zone 19/20	Replace - fire	Possum/ Glider	Large	Cyplas	Possum/ Glider	Large	Stock	Timber	
7	Zone 19/20	Replace - fire	Possum/ Glider	Large	Cyplas	Possum/ Glider	Large	Stock	Timber	
7	Zone 10	Replace - fire	Single Chamber Bat	Timber	Single Chamber Bat	New purchase	Cyplas	Recommend Feathertail Glider, single or double chambered bat box		
7	Zone 10	Replace - fire	Small Parrot	Timber	Small Parrot	Stock	Cyplas			
7	Zone 10	Replace - fire	Spotted Quoll	Tail	Timber	Spotted Quoll	Tail	Stock	Timber	
8	Zone 13 S	Replace - termites	Kingfisher	Timber	Kingfisher	Stock	Timber	Cyplas recommended here as termites have previously damaged boxes, or locate box in adjacent tree		
8	Zone 13 S	Replace - termites	Possum/ Glider	Large	Timber	Possum/ Glider	Large	Stock	Cyplas	Cyplas recommended here as termites have previously damaged boxes
10	Duck Ck	Replace - stolen	2 Chamber Bat	Timber	2 Chamber Bat	New purchase	Cyplas	Recommend finding alternate and less conspicuous host tree for single or double chambered bat box		

Section	Location	Reason for replacement	Box Type	Material	Replacement box type	Source	Material	Comments	
10	Zone 5/6	Replace - fire	Brush-tailed Phascogale	Cyplas	Brush-tailed Phascogale	New purchase	Cyplas		
10	Zone 5/6	Replace - fire	Glider Entry	Rear	Cyplas	Small Parrot	Stock	Cyplas	Entrance sizes and box dimensions very similar, Sugar and Squirrel Glider recorded in Small Parrot nest boxes
10	Kays Rd	Replace - termites	Pardalote	Timber	Pardalote	New purchase	Cyplas	Cyplas recommended here as termites have previously damaged boxes	
10	Kays Rd	Replace - termites	Possum/ Glider	Large	Timber	Possum/ Large Glider	Stock	Cyplas	Cyplas recommended here as termites have previously damaged boxes
10	Zone 8	Replace - fire	Possum/ Glider	Large	Cyplas	Possum/ Large Glider	Stock	Timber	
10	Kays Rd	Replace - cleared	Small Parrot	Timber	Small Parrot	Stock	Cyplas		

2

8. Proposed allocation of nest boxes to NBRZs

8.1 Section 3A and Section 3

A total of 93 nest boxes are required for installation in Section 3A and Section 3 to fulfill the 100% quota and account for the Avenue Road variation. Some NBRZs within Section 3 are already at capacity and will not be selected for further nest box installation. Where nest boxes have been destroyed by termites, replacement boxes will be constructed from Cyplas or placed on adjacent trees.

There were records of small colonies of the threatened Eastern Long-eared Bat inhabiting bat boxes in NBRZs 18 and 20 so bat boxes will be allocated within each of these NBRZs to provide adequate habitat to allow for roost switching to occur (clusters of at least three bat boxes in each NBRZ). There were also several records of other more common bat species in NBRZ 6 as well as other common species of bats in NBRZs 15, 19 and 25. Where NBRZs are not at capacity bat boxes will form a portion of the additional install within each of these NBRZs so that clusters of at least three bat boxes are available within the zone.

There has been records of the threatened Squirrel Glider inhabiting and sometimes breeding in boxes throughout the following NBRZs; 4, 6, 9, 11, 12, 14, 18, 19, 20 and 22. Glider rear entry boxes will be installed within each of these NBRZs so that at least one cluster of three nest boxes are available to Squirrel Gliders in each zone.

Brush-tailed Phascogales have been recorded in nest boxes in NBRZs 4, 6 and 18 so Brush-tailed Phascogale boxes will be installed within these NBRZs so that at least one cluster of three nest boxes are available to Brush-tailed Phascogales in each zone.

Brush-tailed Possums were commonly recorded in most NBRZs and there was a record of a Greater Glider from the clearing supervision data provided for Section 3. Possum / Large Glider boxes will also make up a significant component of the 100% nest box quota installed through Section 3A and Section 3.

The 93 boxes required to be installed in Section 3A and Section 3 are proposed to be installed in NBRZs between NBRZ 1 and NBRZ 22. NBRZs 23 – 26 are at capacity and cannot accept any more nest boxes. Maps showing the locations of the NBRZs for installation of the 100% quota are shown in Figure 1 to Figure 4. A summary of the box types allocated to each zone is presented in Table 16.

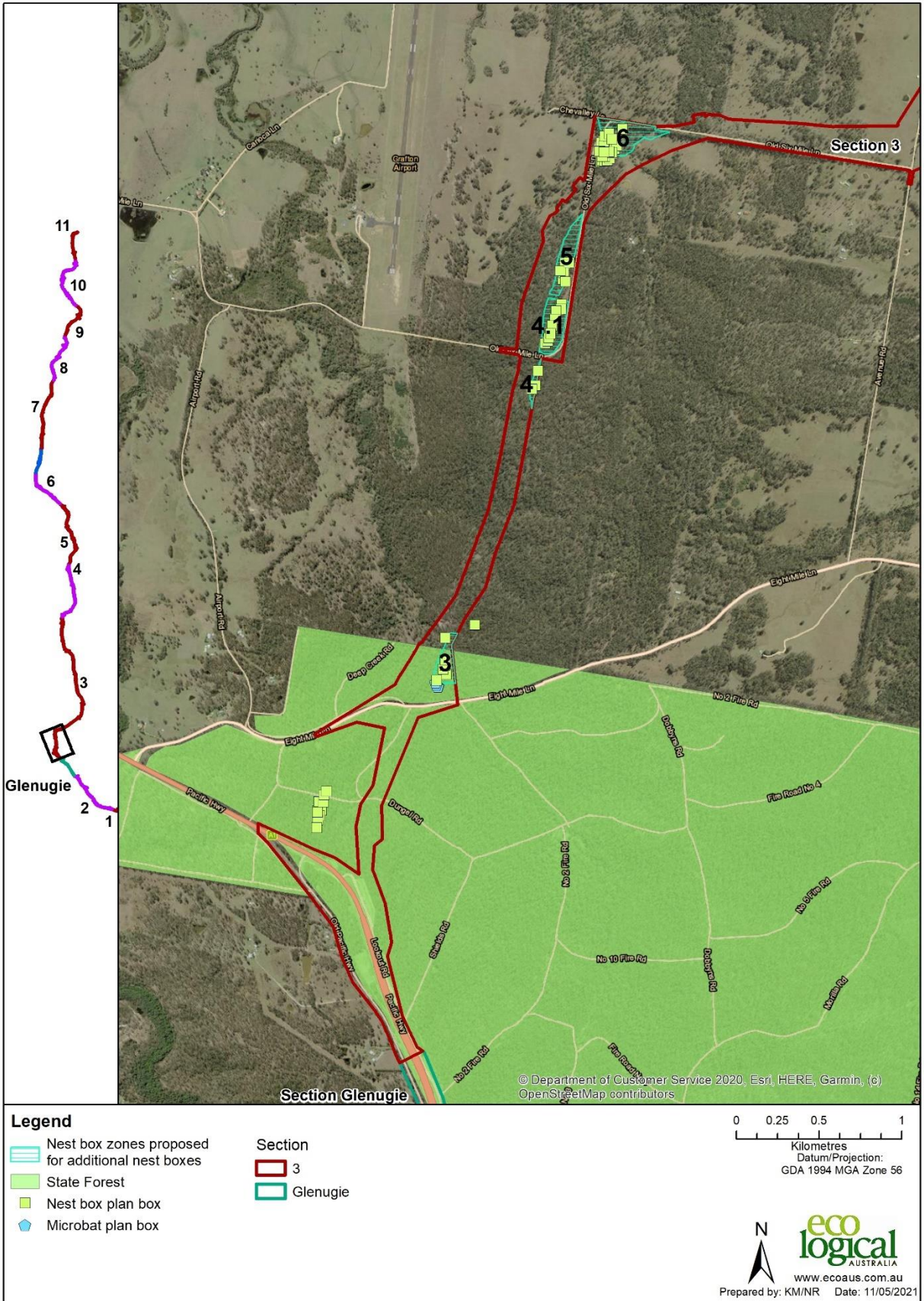


Figure 1. Section 3 NBRZs proposed for 100% nest box quota installation, NBRZs 3, 4, 5 and 6.

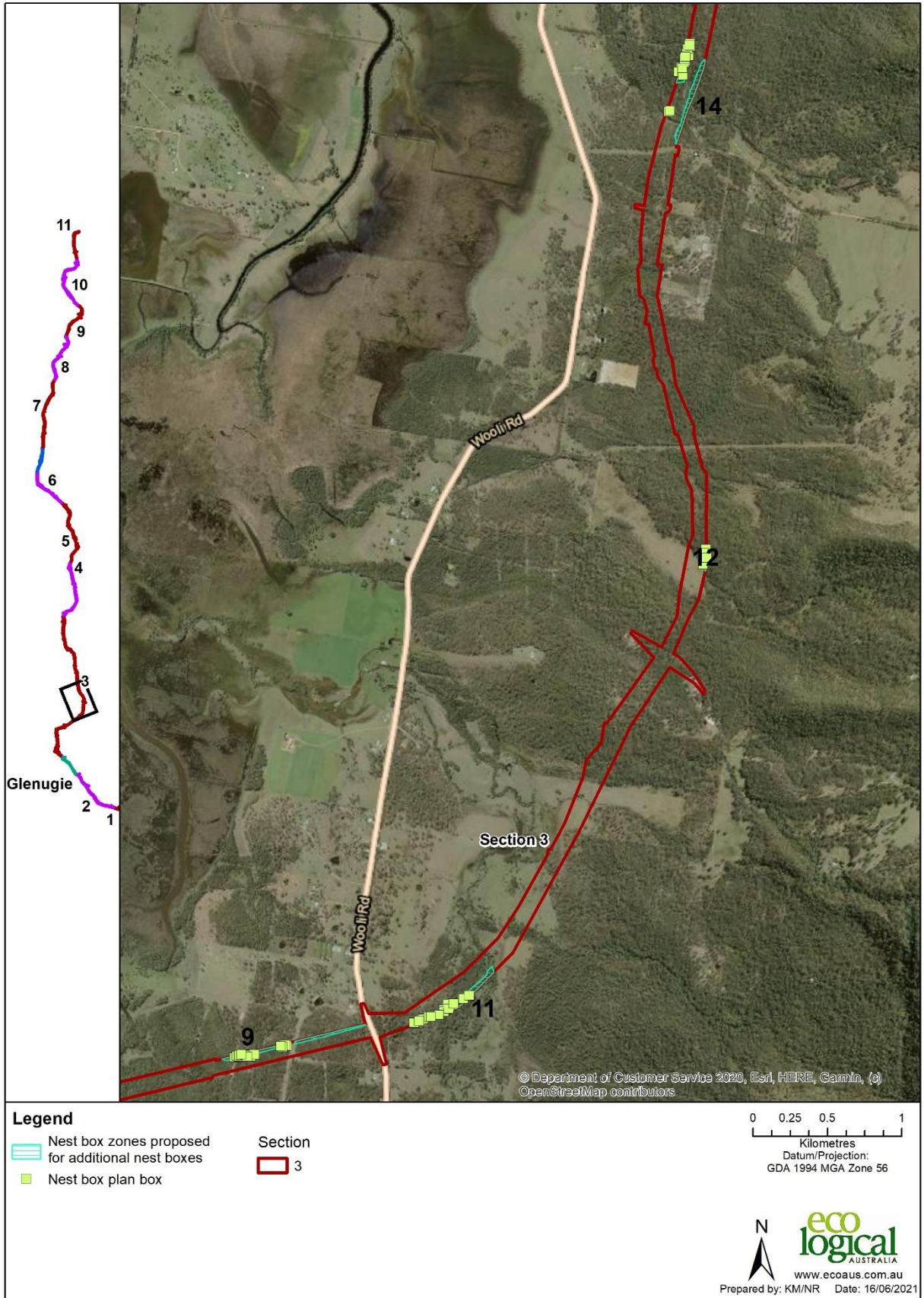


Figure 2. Section 3 NBRZs proposed for 100% nest box quota installation, NBRZs 9, 11 and 12 and 14.

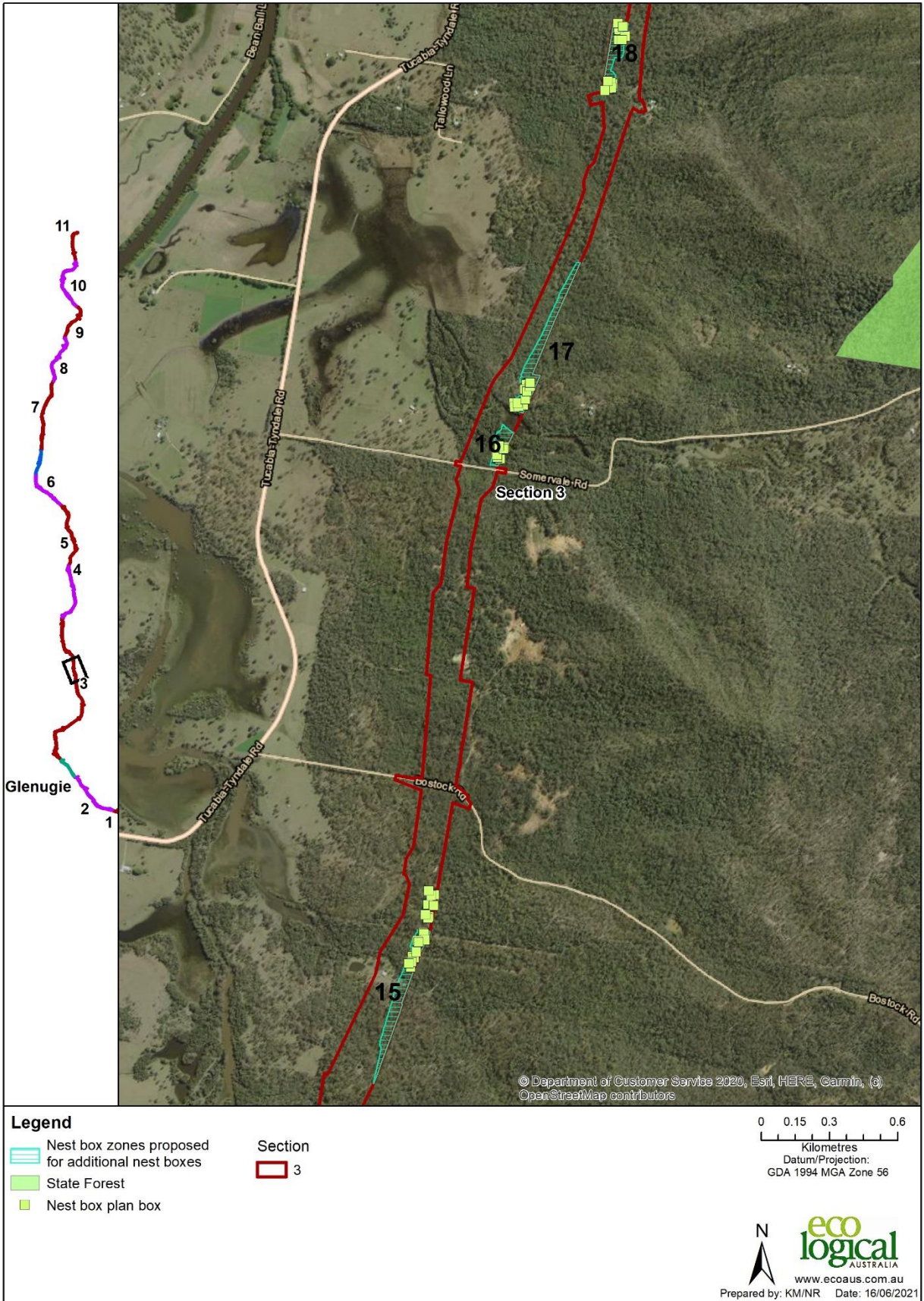


Figure 3. Section 3 NBRZs proposed for 100% nest box quota installation, NBRZs 15, 16, 17 and 18.

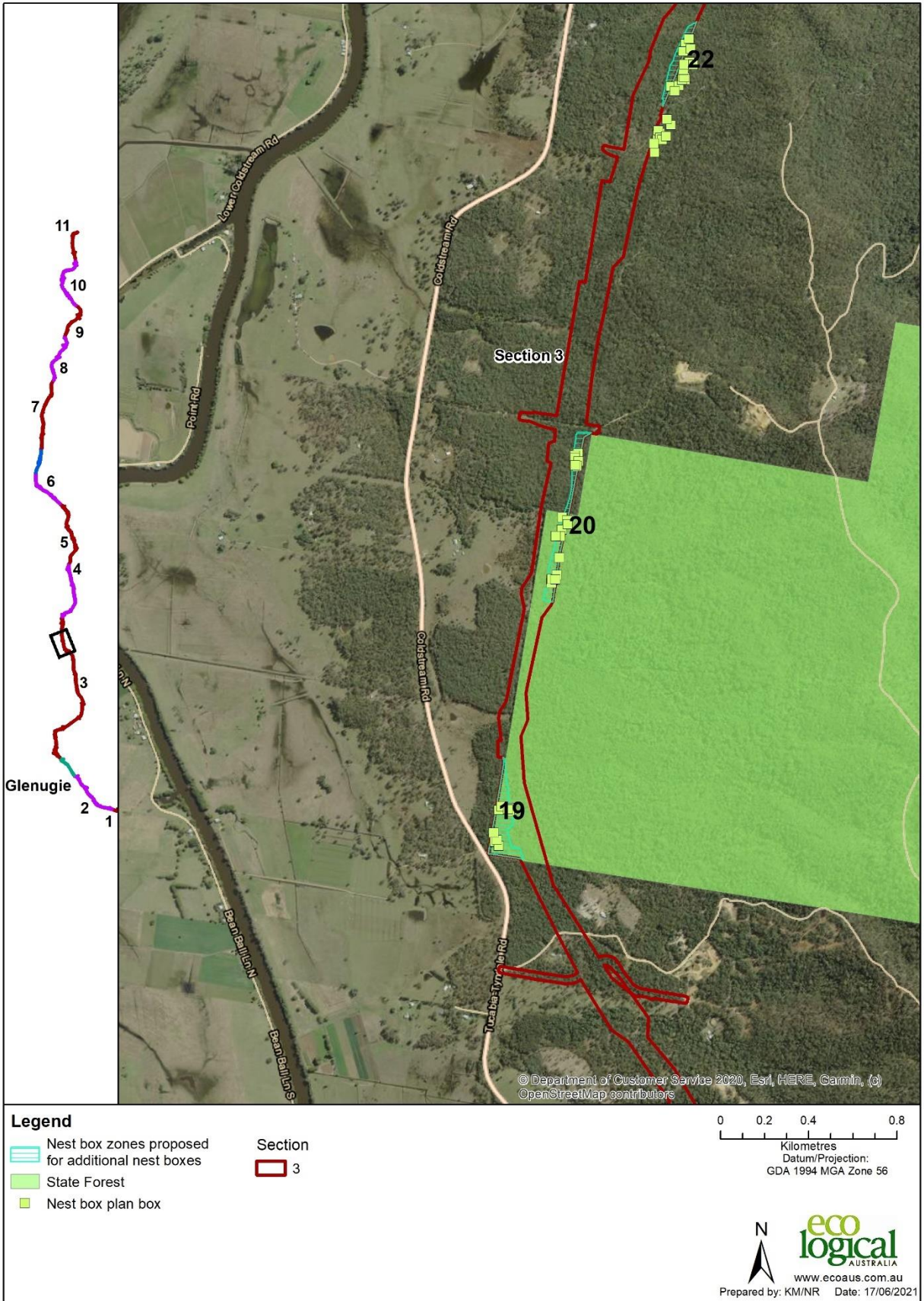


Figure 4. Section 3 NBRZs proposed for 100% nest box quota installation, NBRZs 19, 20 and 22.

8.2 Section 6

A total of two nest boxes are required for installation in Section 6 to fulfill the 100% quota. There were records of *Antechinus* spp., Feathertail Gliders, Ring-tailed and Brush-tailed Possums and Sugar and Squirrel Gliders occupying nest boxes throughout Section 6.

It is proposed that a single Feathertail Glider box be installed in NBRZ 3 to provide a cluster of three suitable boxes for use by Feathertail Gliders (Figure 5). A Glider Rear Entry box is also proposed to be installed within NBRZ 2 which will provide this zone with two clusters of nest boxes able to be used by Possums and Gliders. Both NBRZs lie within an offset property (Lot 1, DP 1186281) which will be maintained for biodiversity in perpetuity. A summary of the box types allocated to each zone is presented in Table 16

8.3 Section 7, Section 8 and Section 9

A total of 57 nest boxes are required for installation in Section 7, Section 8 and Section 9 to fulfill the 100% quota. Some NBRZs within Section 7, Section 8 and Section 9 are already at capacity and will not be selected for further nest box installation. Where nest boxes have been destroyed by termites, replacement boxes will be constructed from Cyplas or placed on adjacent trees. Where nest boxes have been damaged by fires, replacement boxes may need to be installed on alternative trees.

There were records of Squirrel Gliders, Sugar Gliders and Possums throughout Section 7, 8 and 9, largely around NBRZs 19, 20, 27 and 30 in Section 7 and NBRZs 15 and 18 in Section 8. Glider rear entry boxes will be installed within each of these NBRZs (excepting NBRZ 30 which is too small for any additional boxes to be added) so that at least one cluster of three nest boxes are available to Squirrel Gliders in each zone.

There were also records of Long-eared Bats in NBRZ 24 in Section 7 and NBRZ 15 in Section 8. Bat boxes will form a portion of the additional install within NBRZ 24 so that clusters of at least three bat boxes are available within the zone.

Brush-tailed Possums were recorded in several NBRZs and Possum / Large Glider boxes will also make up a significant component of the 100% nest box quota installed through Section 7, Section 8 and Section 9.

The 57 boxes required to be installed in Section 7, Section 8 and Section 9 are proposed to be installed in NBRZs 1, 10, 19, 20, 23, 24 and 27 in Section 7, NBRZ 15 in Section 8 and NBRZ 18 in Section 9. NBRZs 21, 29 and 30 in Section 7 and NBRZs 5, 8 and 13 in Section 8 are at capacity and cannot accept any more nest boxes.

Maps showing the locations of the NBRZs for installation of the 100% quota are shown in Figure 5, Figure 6, Figure 7 and Figure 8. A summary of the box types allocated to each zone is presented in Table 16

8.4 Section 10 and Section 11 to fulfill the 100% quota

A total of 52 nest boxes are required for installation in Section 10 and Section 11.

It is recommended that nest boxes be allocated to those parts of the alignment that supported the highest number of hollow dependent fauna during clearing and/or sites where boxes could be most

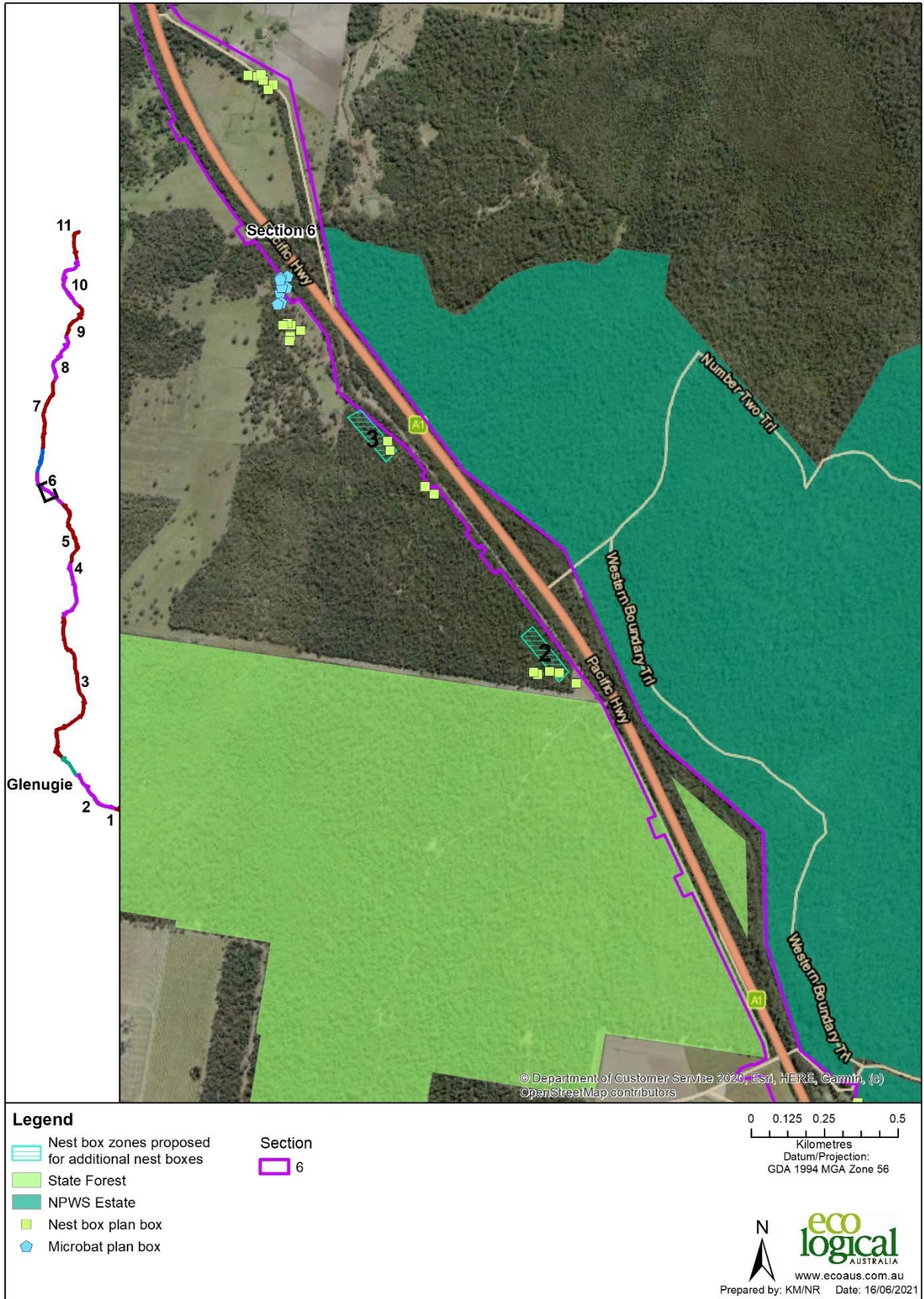


Figure 5. Section 6 NBRZs proposed for 100% nest box quota installation, NBRZs 2 and 3.

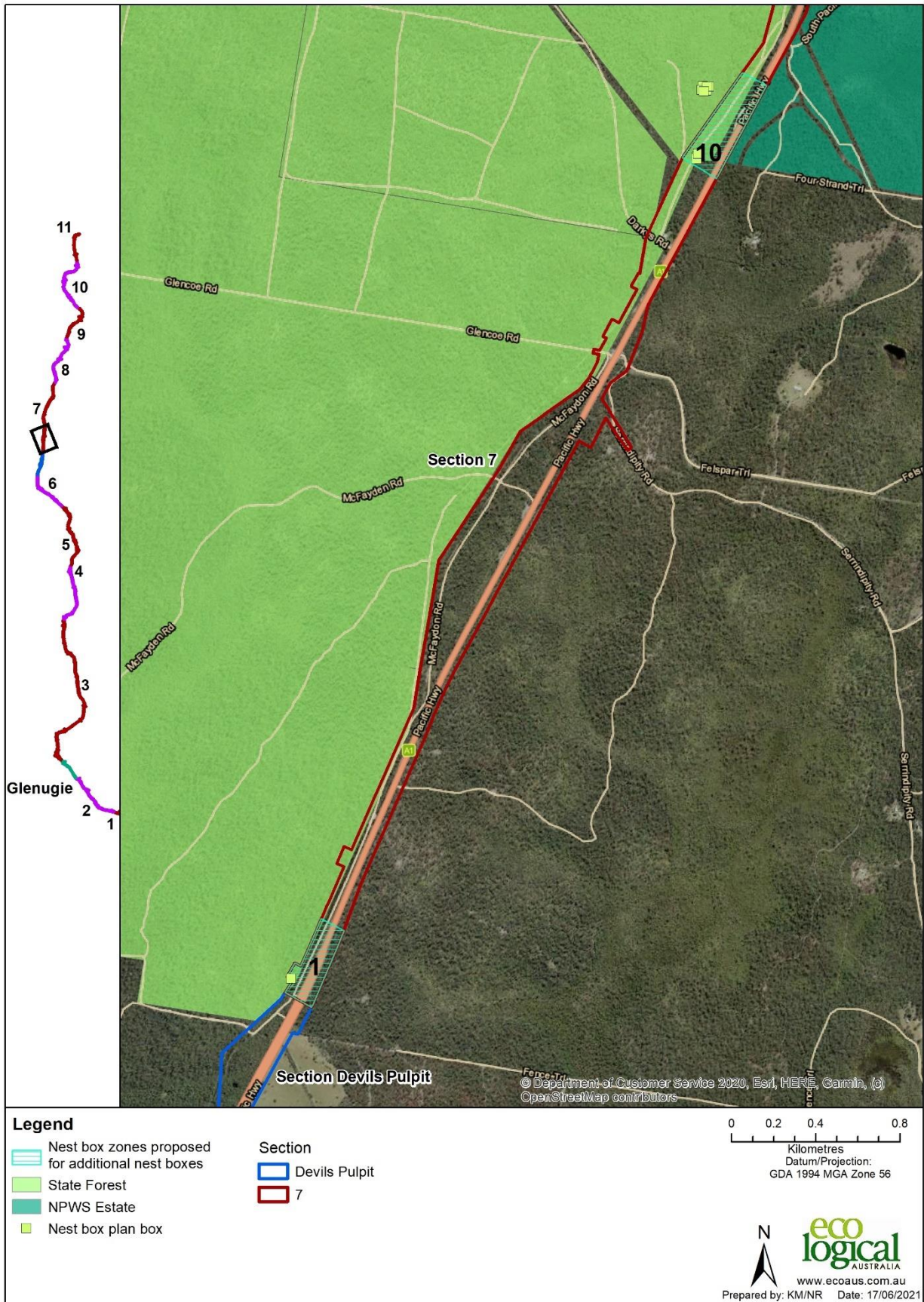


Figure 6. Section 7 NBRZs proposed for 100% nest box quota installation, NBRZs 1 and 10.

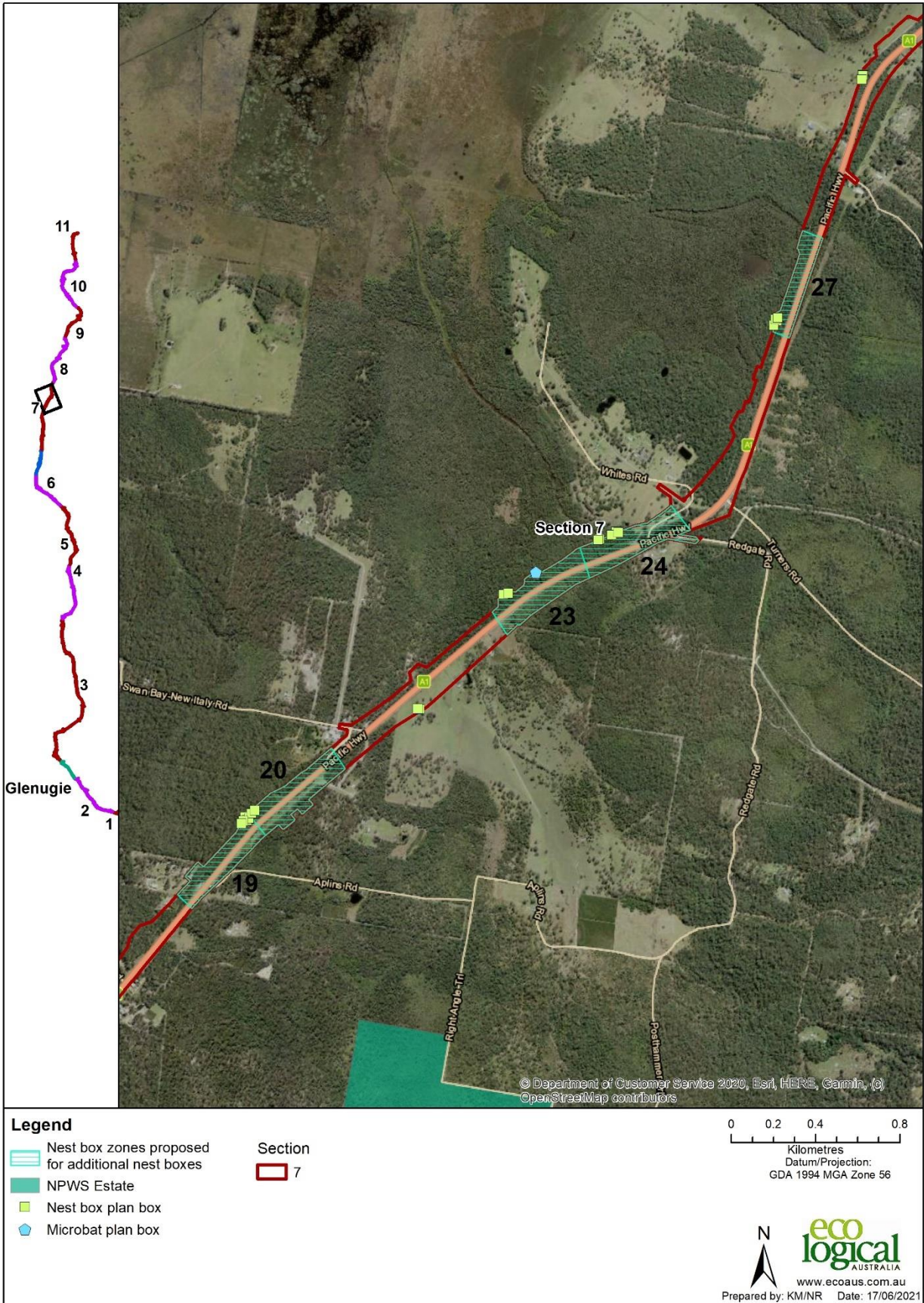


Figure 7. Section 7 NBRZs proposed for 100% nest box quota installation, NBRZs 19, 20, 23, 24 and 27.

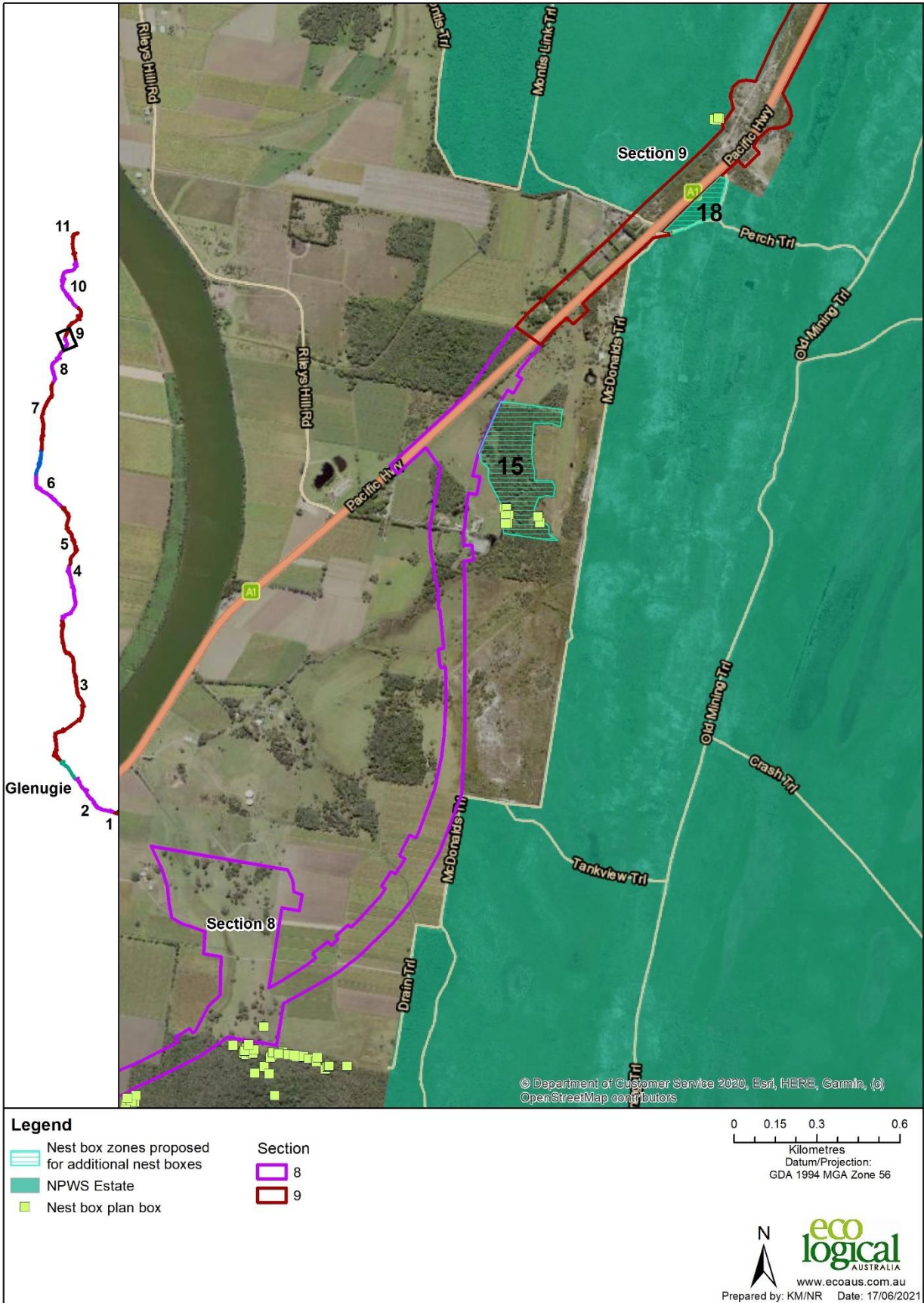


Figure 8. Section 8 and 9 NBRZs proposed for 100% nest box quota installation, NBRZs 15 and 18.

beneficial. There is a very limited amount of vegetation left within the road reserve for the additional boxes. As reported by Sandpiper (2020) during clearing supervision, the southern portion of Section 10 between Back Channel Road and Old Bagotville Road contained Squirrel Gliders and the fragmented habitat between Old Bagotville Road and Lumleys Lane contained a number of parrots.

During the pre-installation inspections to determine the location of suitable nest box replacement zones, ELA recommended utilising offset areas set aside for *Phascolarctos cinereus* (Koala) habitat as potential receptor sites. This recommendation was also made by Sandpiper (2020) in the post-clearing report for Section 10 and 11. Installing nest boxes in koala habitat plantings may enable gliders to establish territories in formerly unsuitable habitat and provide ecosystem benefits such as insect control and pollination. Monitoring such boxes would also provide useful information on rates of colonisation of rehabilitated forest by hollow dependent fauna.

There were records of Squirrel Gliders, Sugar Gliders and Possums throughout Section 10 and 11, in most NBRZs between NBRZ 3 and 35. Glider rear entry boxes will be installed within NBRZs 5, 11, 28, 29, so that at least one cluster of three nest boxes are available to gliders and possums in each zone.

There were records of small colonies of the threatened Eastern Long-eared Bat inhabiting bat boxes in NBRZs 29, 35, and 36 as well as the threatened Southern Myotis inhabiting boxes in NBRZ 40 so bat boxes will be allocated within each of these NBRZs to provide adequate habitat to allow for roost switching to occur (clusters of at least three bat boxes in each NBRZ). There were also several records of other common species of bats in NBRZs 11, 28, 29, 35, 36 and 40. Where NBRZs are not at capacity bat boxes will form a portion of the additional install within each of these NBRZs so that clusters of at least three bat boxes are available within the zone.

The 52 boxes required to be installed in Section 10 and Section 11 are proposed to be installed in NBRZs 5, 11 and 28 in Section 10 and NBRZ 29 in Section 11. NBRZs 3, 6, 7, 8, 35 and 36 are at capacity and cannot accept any more nest boxes. In addition to the existing NBRZs, a number of offset properties will be used as receptor sites for nest boxes. These properties will be maintained for biodiversity in perpetuity. The properties known as APO 317 (Lot 47, DP755691) and APO 318 (Lot 1, DP706869) have been planted out with Koala feed tree species and contain some remnant vegetation suitable for receiving nest boxes for gliders, possums and bats. Similarly, the property known as APO 334 (Lot 2, DP543525) on Lumleys Lane contains some good stands of remnant forested vegetation suitable for receiving nest boxes and open areas that have been planted out with Koala feed tree species. The property known as APO 339 (Lot 61, DP1088684) already contains nest boxes from an early works installation along Kays Road that have been well used by a range of species and is largely forested. This site could also accommodate additional nest boxes and will receive glider rear entry boxes, possum boxes and bat boxes so that at least one cluster of three boxes of the same type are available.

Maps showing the locations of the NBRZs for installation of the 100% quota are shown in Figure 9 to Figure 11. A summary of the box types allocated to each zone is presented in Table 16

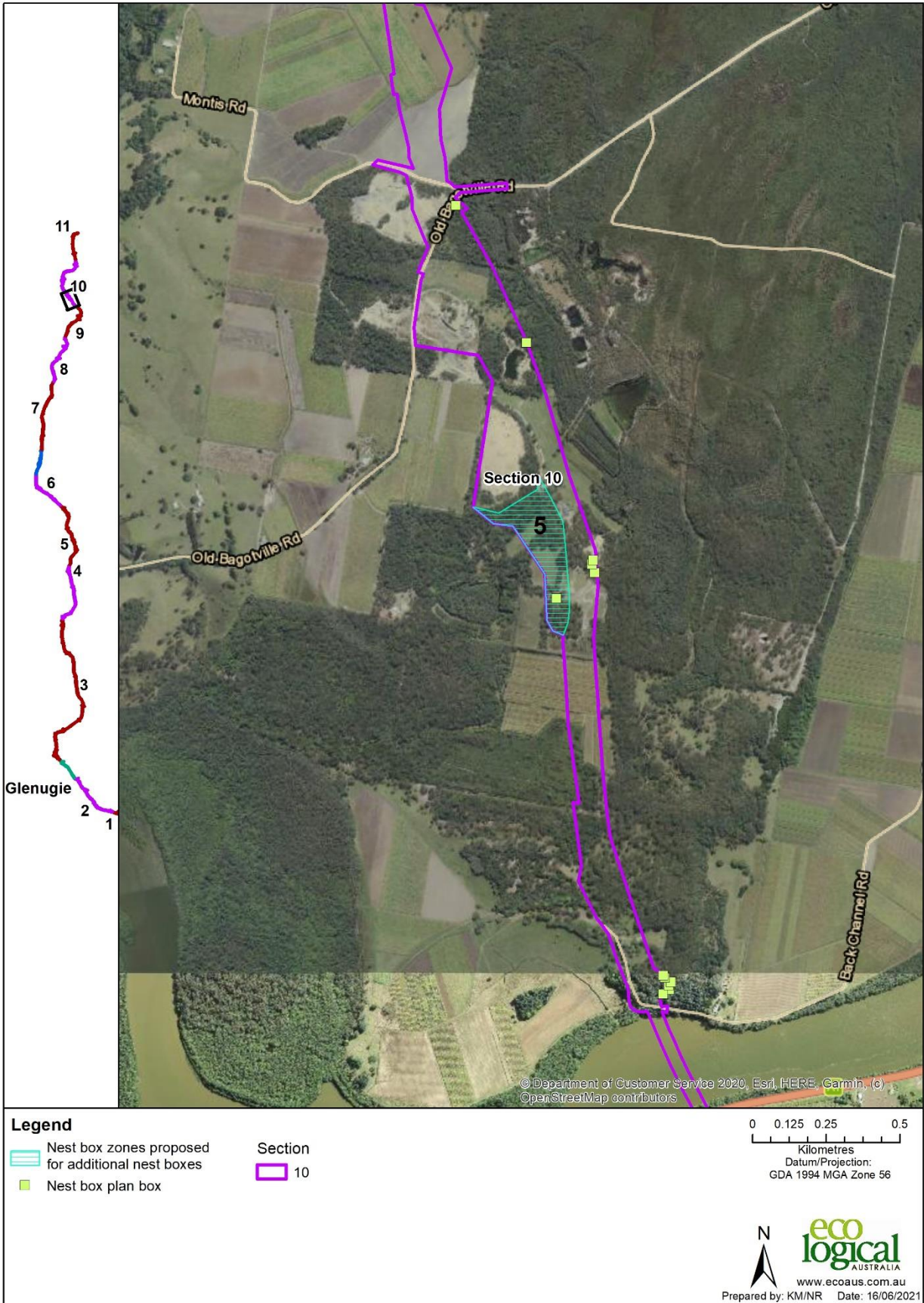


Figure 9. Section 10 NBRZ proposed for 100% nest box quota installation, NBRZ 5.

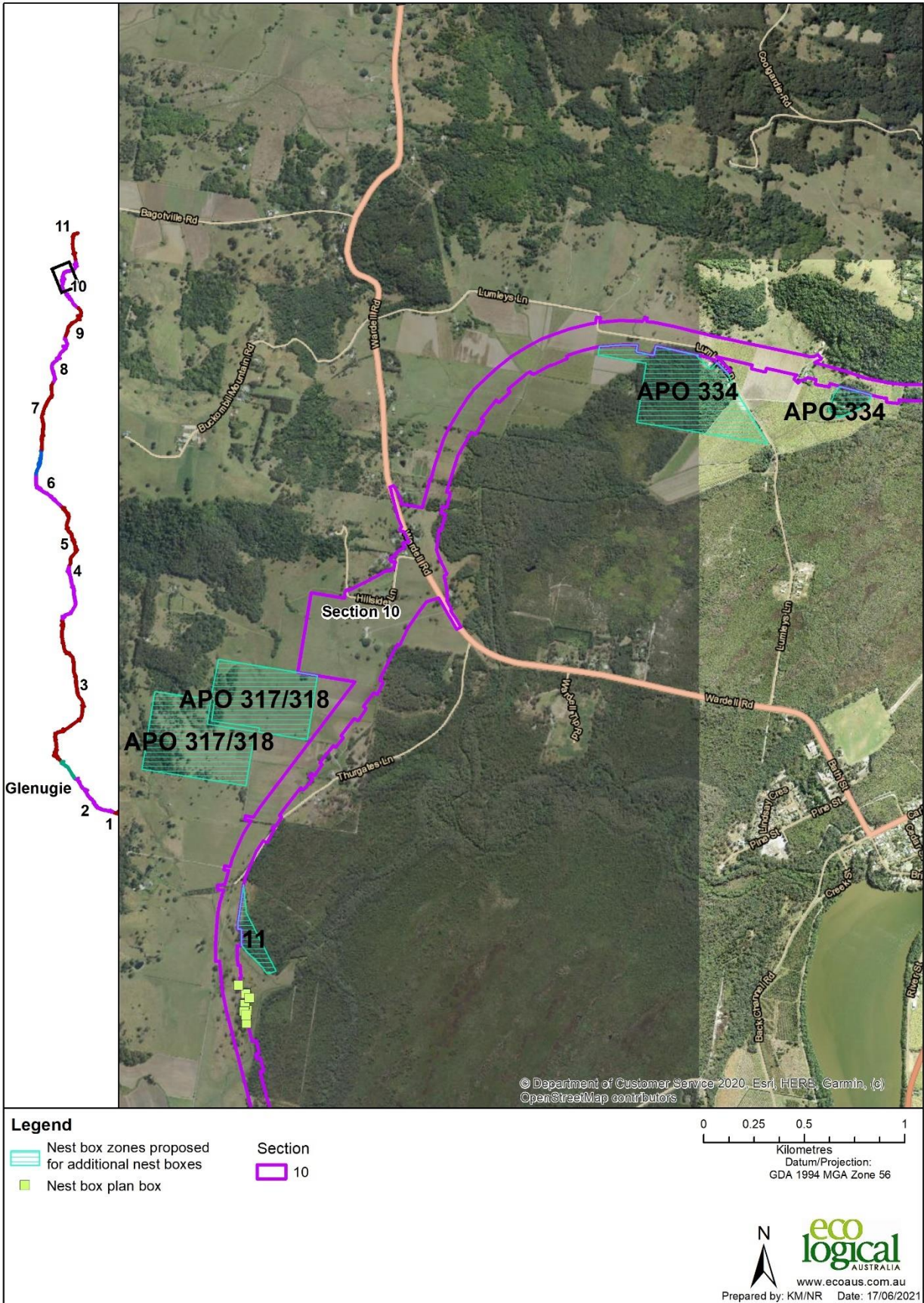


Figure 10. Section 10 offset properties and NBRZ 11 proposed as receptor sites for 100% nest box quota installation.

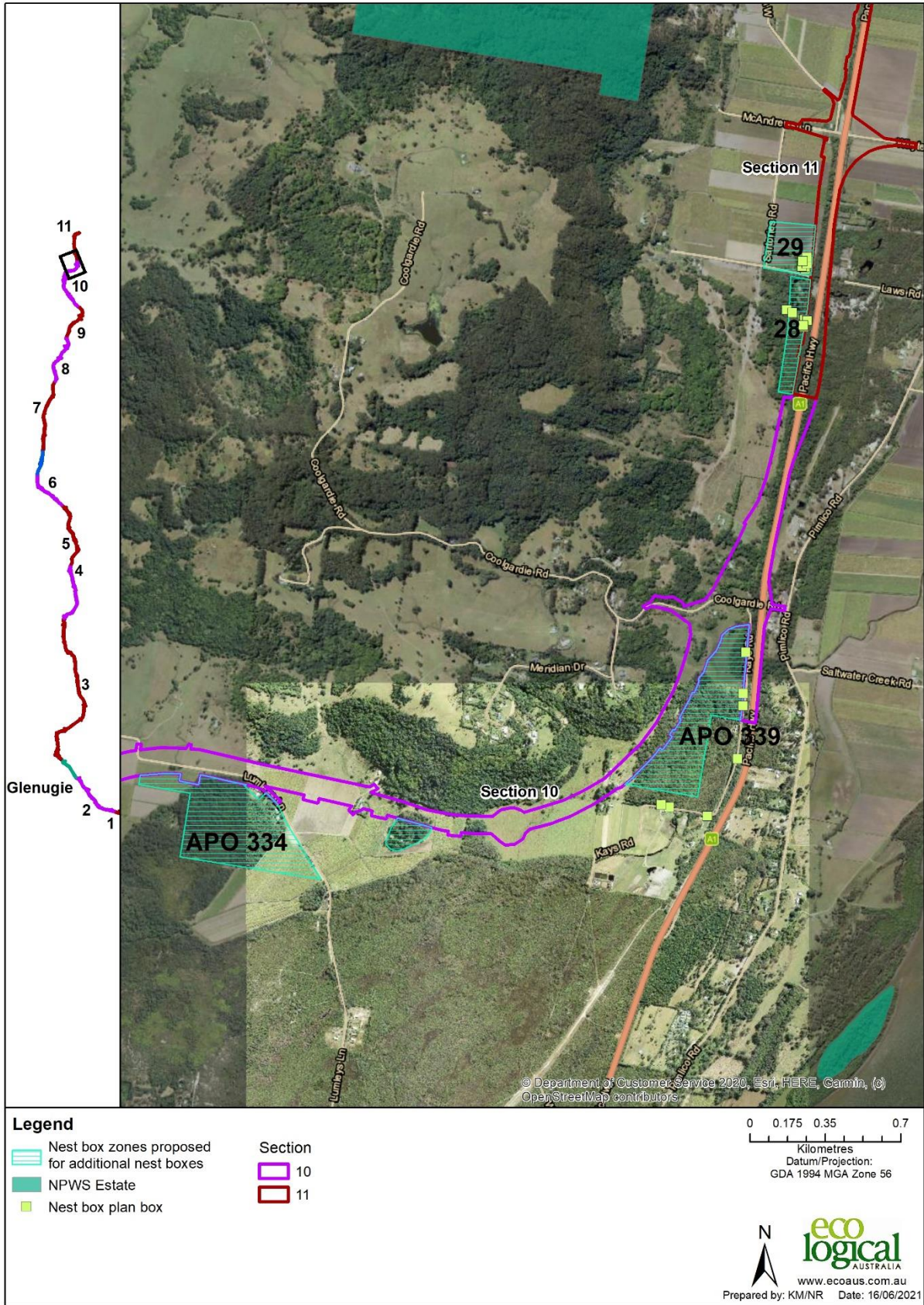


Figure 11. Section 10 and 11 offset properties and NBRZs (28 and 29) proposed as receptor sites for 100% nest box quota installation.

Table 16. Summary of 100% nest box allocation by nest box type and NBRZ for Sections 3 to 11 of the W2B project showing boxes sourced from stock and newly purchased.

Section	NBRZ #	100% newly purchased box type					100% in stock box type						Subtotal	
		Antchns	Bat 2 chbr	Bat 3 chbr	Phscgale	Fthrtl Gldr	Gldr Rear	Possu	Cock/Owl	DollarBrd	Galah	Possu		Quoll
3	1					2	2	1	1					6
3	3		1	1	4		1							7
3	4		1	1	2		3					3		10
3	5	2		1	1									4
3	6	1	1				1							3
3	9	1	1	1	2									5
3	11			1	1	3								5
3	12	2					1	2						5
3	14	1		1		3	2							7
3	15	2			2		1							5
3	16	2			2		2							6
3	17	2	3				2							7
3	18	2	1		2		1							6
3	19	2	2		2	2	1	1						10
3	20	2	1		2		1							6
3	22		1											1
6	2c					1								1
6	3a						1							1
7	1					3	2							5
7	10	3	1		2		2	1					2	11
7	19	1			1		1							3
7	20	2												2

Section	NBRZ #	100% newly purchased box type					100% in stock box type						Subtotal	
		Antchns	Bat 2 chbr	Bat 3 chbr	Phscgale	Fthrtl Gldr	Gldr Rear	Poosum	Cock/Owl	DollarBrd	Galah	Poosum		Quoll
7	23		1	1		3						3		8
7	24	3	1	1			2	1						8
7	27				2			2			1			5
8	15	2	1	1		2	2			3				11
9	18	2					2							4
10	3						3							3
10	5					3	3					3		9
10	11						3					3		6
10	APO 339					2	3	1						6
10	28			1			3				1			5
11	29					2		1						3
11	APO 317		1	2			3					3		9
11	APO 334	3		2			3	3						11
Total		35	17	14	25	26	51	13	1	3	2	15	2	204

9. Conclusions

Following an evaluation of the clearing data provided for Sections 3 to 11 of the W2B Pacific Highway upgrade project, it has been concluded that a total of 204 nest boxes must be installed to complete the 100% quota of nest boxes required to compensate for the loss of HBTs as per the NBMPs and MCoA for the project. This figure was calculated by applying the ratio of the estimated number of nest boxes : estimated number of hollow bearing trees to the actual number of hollow bearing trees cleared to each Section and includes two boxes required as part of the Avenue Road variation 100% quota.

Locations suitable as receptor sites for nest boxes predominantly include existing NBRZs within the project boundary that are not at capacity. Receptor sites have also been selected based on a number of other criteria including the presence of target threatened fauna identified during nest box monitoring inspections and safety of access for nest box installation and future monitoring inspections.

There are also a number of land parcels that have been selected outside of the project boundary on land acquired by TfNSW as offset sites which will be managed and maintained for the purposes of conservation in perpetuity.

The 204 nest boxes required for the 100% quota will comprise a mix of box types including 2 or 3 Chambered Bat Boxes, Antechinus, Brush-tailed Phascogale, Feathertail Glider, Glider Rear Entry and Possum / Large Glider (Table 17). A total of 23 boxes required for the 100% quota will be sourced from those in stock, with the remaining 181 to be newly purchased (Table 17). The 55 replacement boxes will comprise a mix of box types including 2 Chambered Bat Boxes, Antechinus, Barn Owl / Wood duck, Brush-tailed Phascogale, Cockatoo / Owl, Dollar Bird / Crimson Rosella, Galah, Glider Rear Entry, Kingfisher, Pardalote, Possum / Large Glider, Quoll and Small Parrot (Table 17). A total of 39 boxes required for replacement boxes will be sourced from stock with the remaining 16 boxes newly purchased (Table 17). Other than the 62 nest boxes remaining in stock which will be utilised as part of the replacement box quota (where box types match or closely resemble the box type to be replaced) as well as the 100% box quota, any new boxes required to be purchased will be constructed from Cyplas or comprise an artificially created tree hollow (chainsaw hollow).

Table 17. Summary of nest box types to be sourced or created using artificial hollows to fulfil 100% quota and replacement boxes.

Nest box type	100% quota		Subtotal	Replacement boxes		Subtotal	Total
	New	In stock		New	In stock		
2 Chamber Bat	17	0	17	4	0	4	21
3 Chamber Bat	14	0	14	0	0	0	14
4 Chamber Bat	0	0	0	0	0	0	0
Antechinus	35	0	35	0	1	1	36
Barn Owl / Wood duck	0	0	0	2	0	2	2
Brush-tailed Phascogale	25	0	25	3	3	6	31
Cockatoo /Owl	0	1	1	0	7	7	8
Dollar Bird / Crimson Rosella	0	3	3	0	2	2	5

Nest box type	100% quota		Subtotal	Replacement boxes		Subtotal	Total
	New	In stock		New	In stock		
Feathertail Glider	26	0	26	0	0	0	26
Galah	0	2	2	0	2	2	4
Glider Rear Entry	51	0	51	6	0	6	57
Kingfisher	0	0	0	0	3	3	3
Pardalote	0	0	0	1	0	1	1
Possum / Large Glider	13	15	28	0	16	16	44
Quoll	0	2	2	0	1	1	3
Small Parrot	0	0	0	0	4	4	4
Total	179	23	202	16	39	55	257

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Appendix C Monitoring Data

Supplied as a separate digital file

