NSW Roads and Maritime Services

WOOLGOOLGA TO BALLINA | PACIFIC HIGHWAY UPGRADE

THREATENED MAMMAL MANAGEMENT PLAN

Version 1.0

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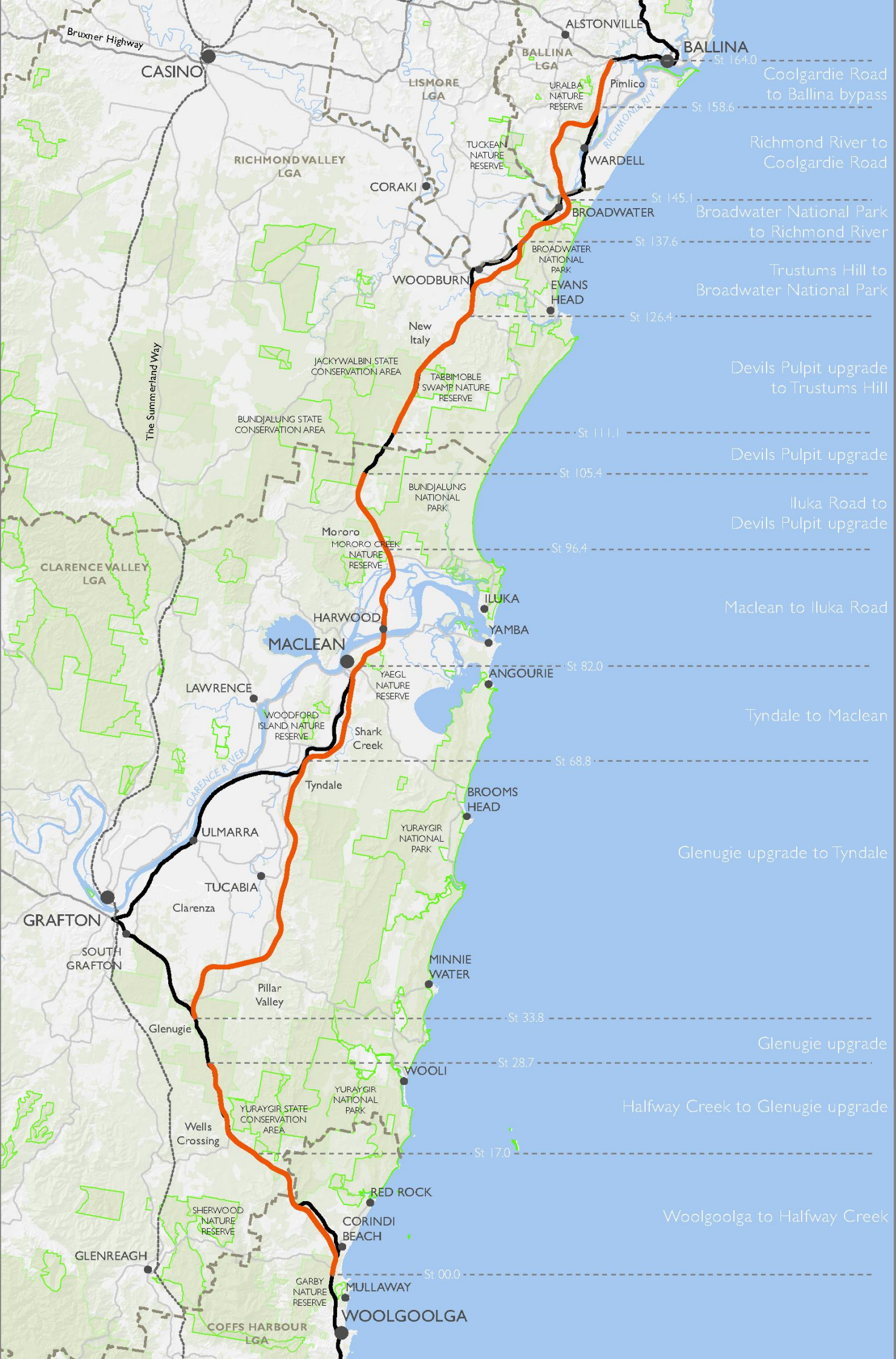
Bruxner Highway
CASINO
ALSTONVILLE
BALLINA
BALLINA LGA
LISMORE LGA
URALBA NATURE RESERVE
Pimlico
RICHMOND RIVER
St 164.0
Coolgardie Road to Ballina bypass
11
St 158.6
Richmond River to Coolgardie Road
10
TUCKEAN NATURE RESERVE
WARDELL
RICHMOND VALLEY LGA
CORAKI
St 145.1
BROADWATER
Broadwater National Park to Richmond River
9
St 137.6
BROADWATER NATIONAL PARK
WOODBURN
EVANS HEAD
Trustums Hill to Broadwater National Park
8
St 126.4
New Italy
JACKYWALBIN STATE CONSERVATION AREA
TABBIMOBLE SWAMP NATURE RESERVE
Devils Pulpit upgrade to Trustums Hill
7
The Summerland Way
BUNDJALUNG STATE CONSERVATION AREA
St 111.1
Devils Pulpit upgrade
St 105.4
BUNDJALUNG NATIONAL PARK
Iluka Road to Devils Pulpit upgrade
6
Mororo
MORORO CREEK NATURE RESERVE
St 96.4
CLARENCE VALLEY LGA
ILUKA
HARWOOD
YAMBA
MACLEAN
Maclean to Iluka Road
5
ANGOURIE
St 82.0
YAEGL NATURE RESERVE
LAWRENCE
WOODFORD ISLAND NATURE RESERVE
Shark Creek
Tyndale to Maclean
4
St 68.8
CLARENCE RIVER
Tyndale
BROOMS HEAD
YURAYGIR NATIONAL PARK
ULMARRA
TUCABIA
Clarenza
Glenugie upgrade to Tyndale
3
GRAFTON
SOUTH GRAFTON
MINNIE WATER
Pillar Valley
St 33.8
Glenugie
Glenugie upgrade
St 28.7
WOOLI
YURAYGIR NATIONAL PARK
YURAYGIR STATE CONSERVATION AREA
Wells Crossing
Halfway Creek to Glenugie upgrade
2
St 17.0
RED ROCK
SHERWOOD NATURE RESERVE
CORINDI BEACH
Woolgoolga to Halfway Creek
1
GLENREAGH
St 00.0
GARBY NATURE RESERVE
MULLAWAY
WOOLGOOLGA
COFFS HARBOUR LGA

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1. Introduction

1.1 Project overview

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval for the Woolgoolga to Ballina (W2B) Pacific Highway upgrade project (the project / the action), on the NSW North Coast. The approval is sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The location of the project is shown in the figure above.

Since 1996, both the Australian and NSW governments have contributed funds to the upgrade of the 664-kilometre section of the Pacific Highway between Hexham and the Queensland border, as part of the Pacific Highway Upgrade Program.

Both governments have a shared commitment to finish upgrading the highway to a four-lane divided road as soon as possible. However, the actual timing of construction, opening to traffic and completion is dependent on funding negotiations between the Australian and NSW governments. Assessments would be adjusted accordingly based on actual opening dates, for example noise and traffic predictions.

The project would upgrade around 155 kilometres of highway and represents the last priority (known as 'Priority 3' in the upgrade program) in achieving a four-lane divided road between Hexham and the NSW/Queensland Border. The project therefore forms a major part of the overall upgrade program and when constructed, would complete the four-lane divided road program.

The project would be jointly funded by the NSW and Australian governments.

The project does not include the Pacific Highway upgrades at Glenugie and Devils Pulpit, which are located between Woolgoolga and Ballina. These are separate projects, with Glenugie now complete and Devils Pulpit under construction. Altogether, these three projects would upgrade 164 kilometres of the Pacific Highway. The project does include a partial upgrade of the existing dual carriageways at Halfway Creek.

A more detailed description of the Woolgoolga to Ballina Pacific Highway upgrade is found in the Pacific Highway upgrade: Woolgoolga to Ballina Environmental Impact Statement prepared by Roads and Maritime in December 2012.

1.2 Purpose and objectives of the management plan

This threatened mammal management plan addresses the impacts, mitigation and monitoring approach for the:

- Rufous Bettong (*Aepyprymnus rufescens*).
- Spotted-tailed Quoll (*Dasyurus maculatus maculatus*).
- Brush-tailed Phascogale (*Phascogale tapoatafa*).
- Long-nosed Potoroo (*Potorous tridactylus*).
- Cave-roosting Bats (Little Bentwing-bat *Miniopterus australis*, Eastern Bentwing-bat *Miniopterus schreibersii oceanensis*, Southern Myotis (*Myotis macropus*), Large-eared Pied Bat *Chalinolobus dwyeri)*.

Collectively, these species have been referred to as 'threatened mammals' in the remainder of the management plan. The management of other threatened mammals, namely Koala, Squirrel Glider and Yellow-bellied Glider are included in the Koala management plan and Threatened glider management plan. This plan as with other threatened species management plans prepared for the project focuses on species identified in the EIS at greatest risk from the project.

The objectives of the plan include providing:

- A description of the mitigation measures that would be implemented during pre-construction, construction and operation of the project to minimise impacts on threatened mammals.
- A description of program to monitor the effectiveness of these mitigation measures and inform an adaptive management approach.

1.3 Management structure and plan updates

Management structure

This plan provides a framework for any part of the proposed upgrade between W2B where the threatened subject species would be impacted. This plan would be updated detailed design or pre-construction stage of any proposal that may affect threatened species relevant to this plan. The final management plan would be specific to the project section, stage, program of works or singular element of infrastructure which makes-up the overall W2B upgrade. The plan would operate in conjunction with the Construction Environmental Management Plan (CEMP) and project specific flora and fauna management plan (FFMP), or may be incorporated into a wider framework that includes such plans.

Roads and Maritime would finalise this plan in consultation with the NSW Department of Planning and Infrastructure (DoPI) and NSW Office of Environment and Heritage (OEH).

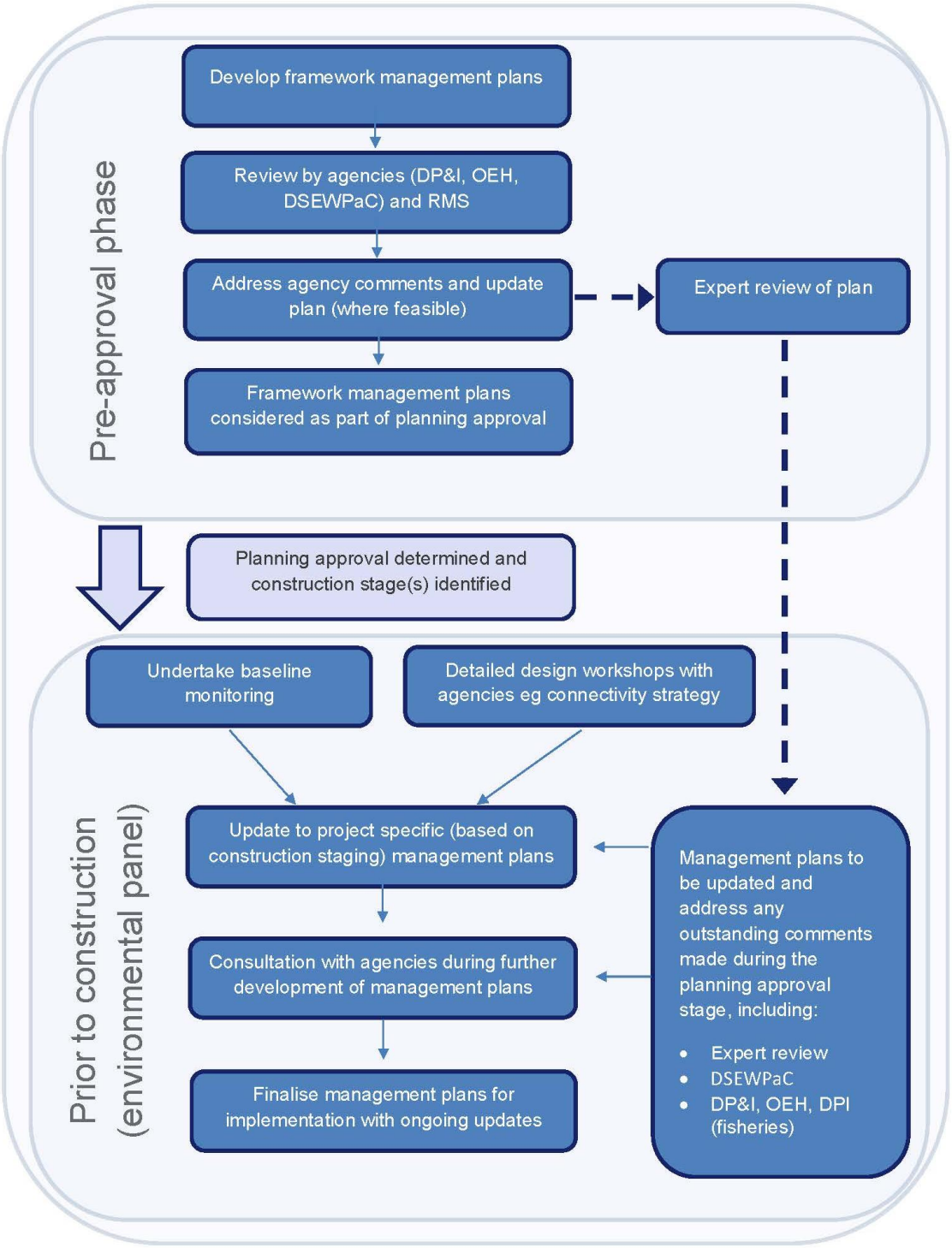
General responsibilities for environmental management would be outlined in the CEMP and FFMP. Responsibilities for implementation of this plan have been described throughout and summarised in **Chapter 8**. Following approval of the plan, the construction contractor and the contractors ecologist engaged for the relevant project sections would be responsible to oversee implementation of the plan

Plan updates

The plan is intended to be a dynamic document subject to continual improvement. The management plan would be updated as required to meet the mitigation and management measures committed to in the W2B Environmental Impact Statement (EIS) and Preferred Infrastructure Report (PIR) and any Condition of Approval (CoA) for the project. Prior to implementation, the plan would be updated following independent expert review to incorporate any necessary changes that arise from that review. The process for the update of the plan is illustrated in **Figure 1-1** below.

This plan identifies the general locations proposed for conducting monitoring and the methods, variables and timing of the proposed monitoring program. Details have been provided on the parameters for the selection of the final monitoring sites, both impact and control sites. It is not possible to pre-select the monitoring sites at this point in the planning and design process, as this requires consultation with affected landowners. The final selection of monitoring sites would be subject to further interrogation through the implementation of targeted surveys (refer to **Section 4.3.1**) and confirmation of landowner access and would be presented in the first annual monitoring report with the intention of repeated sampling to be conducted at these locations.

Figure 1-1 Process to develop management plan



1.4 Plan authors and expert review

This management plan was prepared by Valerie Hagger and Chris Thomson of Sinclair Knight Merz (SKM).

Chris is a group practice leader for ecology with a Bachelor of Applied Science and Graduate Certificate in Natural Resources and seventeen years professional experience managing biodiversity assessments and scientific reporting. He is a highly experienced field ecologist with extensive experience on major road projects with the Roads and Maritime, having worked widely throughout NSW as the technical lead on a range of environmental assessments including several Pacific Highway upgrades, the Hume Highway, Great Western Highway, Princes Highway and New England Highway along with numerous large and small arterial road projects including the M5, M4, Westlink M7 and Westconnex.

Chris has comprehensive knowledge of Commonwealth and NSW threatened species legislation, policies and guidelines and has extensive experience in the design of avoidance and mitigation measures for minimising impacts on threatened species with a high level of experience on infrastructure projects including the development of compensatory habitat and offset strategies, biodiversity connectivity strategies, mitigation and monitoring strategies and threatened species management plans.

Valerie has a Bachelor of Science and Master of Conservation Biology. She is a Senior Ecologist with ten years environmental consulting experience specialising in ecological survey, assessment and monitoring and environmental impact assessment (EIA). She has successfully project managed numerous biodiversity and environmental projects in Australia and the United Kingdom, and has been the ecology technical lead for several EIS projects.

Valerie is competent in conducting baseline flora and fauna surveys, vegetation surveys and mapping, assessing impacts on ecological values, developing mitigation measures, management plans and monitoring strategies for threatened species and ecological communities and developing offsets

Expert review of the plan

An expert review of the plan was undertaken in August 2013 by Dr Martin Schulz. Martin has more than 30 years of experience in conducting fauna surveys, research and monitoring, including conducting PhD research on the Golden-tipped Bat (*Kerivoula papuensis*) at a number of sites across north-eastern NSW including Woolgoolga Flora Reserve. His experience includes research of bat usage of culverts and bridges (including abandoned Fairy Martin nests in these structures), which has been published in a number of journals including *Emu* and the *Australasian Bat Society Newsletter*. Martin knows the fauna of the area well and was team leader of a number of Comprehensive Regional Assessment (CRA) surveys carried out by the Office of Environment and Heritage (OEH) in the region and also a member of a team investigating the fauna in Wedding Bells State Forest. He also has a good knowledge of the fauna along the existing highway, having traversed the current route and roads in the Pillar Valley/Tyndale areas over a 5-year period while residing at Minnie Water. He has worked on a number of projects involving highway upgrades, including an investigation of the impacts of roads on Koalas (at Bonville, with Australian Museum Consulting) and investigations of fauna occurring around crossings of the Hume Freeway between Campbelltown and Mittagong.

A curriculum vitae for Dr Martin Schulz is provided in Appendix A, and a copy of his review of the management plan is attached as Appendix B. The recommendations provided in this review have been summarised in Table 1-1. The table also identifies how each of the recommendations have been addressed. Recommendations have been addressed in one of three ways:

- Adopted - plan updated.
- Adopted - plan to be updated prior to implementation.
- To be reviewed - recommendation to be reviewed further by Roads and Maritime prior to implementation.

Table 1-1 Summary of recommendations from the expert review and how addressed in this plan

ID No	Comment / Recommendation	How recommendations would be addressed
TMMP1	Suggest including more information regarding methods of trapping during the pre-clearance survey	To be reviewed prior to implementation
TMMP2	Recommend further consideration of seasonal factors in pre-clearance surveys	Adopted- plan to be updated prior to implementation
TMMP3	Specific information regarding features and furniture in crossing structures is limited	Adopted- plan to be updated prior to implementation
TMMP4	Specific information regarding permanent fauna exclusion fencing where there are no designated crossing structures is limited	To be reviewed prior to implementation
TMMP5	Recommend the management plan include provision for additional areas of fauna exclusion fencing and/or adaption of crossing structures or potential crossing structures post-construction, if new “hotspots’ are detected post-construction	Adopted- plan to be updated prior to implementation
TMMP6	Recommend that predators be monitored and predator control undertaken in locations where activity is detected for the duration of the monitoring program	To be reviewed prior to implementation
TMMP7	Consider more targeted monitoring of road kill	Adopted- plan to be updated prior to implementation
TMMP8	Ensure offset areas support populations of the species confirmed to occur within the project area	Adopted- plan updated
	Rufous Bettong:	
TMMP9	The management plan should address the potential for this species to occur outside of forested habitat	Adopted- plan to be updated prior to implementation
TMMP10	The plan should include initial findings of the monitoring program for this species in the Glenugie Upgrade, even if it is just initial observations and thoughts by the ecologist involved	Adopted- plan to be updated prior to implementation
TMMP11	If possible, consider pre-construction monitoring in hot spots, particularly in the Pillar Valley (Section 3) and Tyndale to Harwood (Section 4) where the species also occurs in other habitats than forested vegetation types: rank grassland in cleared/semi cleared pasturelands (in former) and rank grassland in sugar cane plantations (latter)	Adopted- plan to be updated prior to implementation
	Brush-tailed Phascogale:	
TMMP12	Design of nest boxes and instalment methodology should follow other projects where they have been successfully used	Adopted- plan updated
TMMP13	Need to avoid undertaking pre-clearance surveys or monitoring during the male die-off period: after the mating period which occurs in May and June, plus the following months when only adult females are about until late spring/early summer. Therefore recommend trapping in summer (January) and autumn (March-April)	Adopted- plan to be updated prior to implementation
	Spotted-tailed Quoll:	
TMMP14	Habitat exclusion zones for this species should consider low escarpments traversed by the project area which may be used as den sites. Recommend that the detailed design include additional habitat inclusion zones in such areas if data indicate the presence of quolls.	Adopted- plan to be updated prior to implementation
TMMP15	As this species has not been conformed to occur in the project area even if occasional individuals are present it will be very difficult to establish meaningful monitoring sites and investigate population trends.	Adopted- plan to be updated prior to implementation
	Long-nosed Potoroo	
TMMP16	The only known population is in the Wardell heath (Section 10). However, in Table 2.1 it is listed as occurring in Sections 1-3 and 6-11. Should this be addressed in the management plan?	Adopted- plan updated
TMMP17	Exclusion fence all potential wet and dry heath habitats bordering the highway footprint in the Wardell heath area	To be reviewed prior to implementation
TMMP18	Overpasses for this species in Wardell heath area to be planted out with a continuous cover of dry heath species which occur in the surrounding areas	Adopted- plan to be updated prior to implementation

	Cave-dwelling Bats	
TMMP19	Need to take into consideration the potential for some of these species to occur in tree hollows, Fairy Martin next etc.	Adopted- plan to be updated prior to implementation
TMMP20	Need to take seasonal activity into consideration during the pre-clearance surveys	To be reviewed prior to implementation
TMMP21	Need to consider bats in the design of connectivity structures	Adopted- plan to be updated prior to implementation
TMMP22	Need to outline approaches to be set in place to minimise the death of individual bats excluded from blocked up roosts as a result of the removal process if there is a lack of alternate roosts	Adopted- plan to be updated prior to implementation
TMMP23	General suggestions	To be reviewed prior to implementation

2. Threatened mammal populations

2.1 Background

The threatened mammals are listed as follows under the NSW *Threatened Species Conservation Act 1995* (TSC Act):

- Rufous Bettong – vulnerable.
- Spotted-tailed Quoll – endangered.
- Brush-tailed Phascogale – vulnerable.
- Long-nosed Potoroo – vulnerable.
- Little Bentwing-bat – vulnerable.
- Eastern Bentwing-bat – vulnerable.
- Southern Myotis – vulnerable.
- Large-eared Pied Bat - vulnerable

Two of these species are also listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act):

- Spotted-tailed Quoll – endangered.
- Long-nosed Potoroo – vulnerable.

2.2 Existing knowledge

2.2.1 Habitat requirements and known or expected occurrence

A brief profile of the habitat requirements and known and expected occurrence of these threatened mammals are provided in **Table 2-1** and figures contained in **Appendix B**. The local distribution and abundance of the threatened mammals within the project are also described in Table C-2 of the Biodiversity Assessment Working Paper (Roads and Maritime 2012).

Table 2-1 Habitat requirements, local abundance and distribution of threatened mammals within the project

Species	Habitat requirements	Records in 10 km of the project [3]	Identified records and project section	Project section known or potential to occur within
Rufous Bettong[1]	Prefer forests with a grassy to sparse understorey including coastal forest, tall wet sclerophyll forest and dry forests west of the Great Diving Range. It is most commonly found on sites derived from sedimentary rock and in north-eastern NSW in forests characterised by Spotted Gum (*Corymbia maculata* and *C. henryi*). Broad habitat requirement/s: tall moist eucalyptus forests and woodlands.	208	Rufous Bettong was recorded in Sections 1-3 and predicted to occur in Section 6-8. Numerous records exist in dry open forest and woodlands north of the Halfway Creek Service Centre, and numerous road kills on Six Mile Lane and Airport Road have been reported (Sections 1 and 2 and the southern end of Section 3). Records for this population in the southern end of the project extend up to Section 3 in the Pheasants Creek and upper Coldstream localities and Sections 1-3 is considered a hotspot for this species.	Section 1 to 8
Brush-tailed Phascogale[1]	Preferred habitat is dry open forest with a sparse open understorey, however, has been located in heath, swamps and rainforest and wet sclerophyll forest. Breeding habitat for this species are hollow trees, logs or stumps with entrances > 2.5 cm wide. Broad habitat requirement/s: dry, open sclerophyll forests.	117	Suitable habitat for Brush-tailed Phascogale was identified north from Halfway Creek to Glenugie (Section 1-4) and the species was confirmed in Section 2 and 4 and 6-8.	Section 1 to 9
Spotted-tailed Quoll	The species is very widespread throughout all areas and habitats of the North Coast Bioregion. Individual animals inhabit hollow bearing trees, fallen logs, small caves, and rocky areas (such as boulder fields and cliff faces) (Department of Environment, Climate Change and Water (DECCW) 2012b). Broad habitat requirement/s: rainforests, open woodlands, coastal heathlands and inland riparian forests.	64	The Spotted-tailed Quoll was not confirmed in project corridor. Also, there are no records of particular clusters near the project that would suggest an important population exists. However based on the habitats present, in particular the larger state forests and conservation reserves, two main areas exist which may represent important habitat for regional populations. These are the areas from Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections 1 and 2) and Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).	Section 1 to 11
Long-nosed Potoroo	This species is known to inhabit coastal heaths and sclerophyll forests (dry and wet) and requires a dense understorey with occasional openings. This species is commonly associated with sandy loam soils (Department of Environment, Climate Change and Water (DECCW) 2012c). Broad habitat requirement/s: coastal heath, dry and wet sclerophyll forests.	9	The Long-nosed Potoroo was not confirmed in project corridor. An isolated population is known from Wardell Heath in Section 10 and associated with the wet and dry heath habitats on sandy soils. Section 10 of the project would traverse around this habitat on the western side and not directly involve a loss of habitat for the Long-nosed Potoroo. Similar habitats on sandy soils with a Eucalypt canopy and heathy understorey also occur to the west of the alignment near chainage 146500 and 148000, while the species has not been confirmed in this location, it should be considered suitable habitat. Up to 10 hectares of wet and dry heath along the edges of the existing highway would be removed for the project, this provides potential habitat for this species, however there are no recent accounts of populations present near the highway.	Section 1 to 3, and Section 6-11

Species	Habitat requirements	Records in 10 km of the project [3]	Identified records and project section	Project section known or potential to occur within
Little Bentwing-bat[2]	This species is a cave-dwelling bat that also roosts in abandoned mines, tunnels, stormwater drains and buildings. They inhabit well-timbered areas such as *Melaleuca* swamps, vine thicket and forests (rainforests, coastal, and sclerophyll). Broad habitat requirement/s: rainforest, wet and dry sclerophyll forest, swamps and coastal scrublands and caves.	221	Little Bentwing-bat were captured and recorded in all sections and appear to be relatively common. Locations of roost sites were not identified.	Section 1 to 11
Eastern Bentwing-bat[2]	This species is cave dwelling, but also use structures such as abandoned mines and road culverts. They inhabit forests (rainforests, sclerophyll, monsoon, *Melaleuca*), open woodlands and open grasslands. Broad habitat requirement/s: caves and forests.	20	Calls for Eastern Bentwing-bat, were recorded in Section 1-2, 6-8 and 9-11. They are expected to occur in suitable habitats throughout all project sections (Section 1-11).	Section 1 to 11
Southern Myotis[2]	This species roosts in caves near water, amongst vegetation and tree hollows, and in man-made structures such as bridges, mines, tunnels, culverts and stormwater drains. They preferentially select caves that overhang ponds. They are generally associated with permanent water bodies at low elevations in flat or undulating, uncleared country. Broad habitat requirement/s: woodlands, open forests near water.	29	Southern Myotis were recorded in Sections 1-2 and 6-8 and 9-11 from positive call identification. They are expected to occur in suitable habitats throughout all project sections (Section 1-11).	Section 1 to 11
Large-eared Pied Bat[2]	Roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (Petrochelidon ariel), frequenting low to mid-elevation dry open forest and woodland close to these features. Females have been recorded raising young in maternity roosts (c. 20-40 females) from November through to January in roof domes in sandstone caves and overhangs. They remain loyal to the same cave over many years. Found in well-timbered areas containing gullies. The relatively short, broad wing combined with the low weight per unit area of wing indicates manoeuvrable flight. This species probably forages for small, flying insects below the forest canopy. Likely to hibernate through the coolest months. It is uncertain whether mating occurs early in winter or in spring	42	Not recorded from targeted surveys, suitable habitat in all forested areas particularly Eucalypt dominated open forests and woodlands.	Section 1 to 11

Broad habitat requirement/s from Table D1 (Appendix D) of the Biodiversity Assessment Working Paper (Woolgoolga to Ballina Planning Alliance 2012).
[1] Habitat requirements from Table C11 (Appendix C) of the Biodiversity Assessment Working Paper (Woolgoolga to Ballina Planning Alliance 2012).
[2] Habitat requirements from Churchill (2008).
[3] Atlas of NSW Wildlife (OEH 2013).

2.3 Key threats

All identified mammal species are threatened by habitat loss, particularly any direct loss or impact to habitats needed for life-cycle events associated with breeding habitat, foraging or shelter resources. Indirect impacts include fragmentation of habitat leading to isolation and loss of population viability. Further specific threats are described in the following.

The Rufous Bettong and the Brush-tailed Phascogale are threatened from to habitat loss and fragmentation as a result of forest clearing for logging, agricultural expansion and urban development (DECCW 2012a). Habitat fragmentation leads to increased predation by foxes and cats and reduced habitat quality at the forest edges. The Brush-tailed Phascogale is particularly sensitive to the loss of hollow-bearing trees (Queensland Museum 2007). These species are also sensitive to the loss of foraging and shelter resources resulting from inappropriate fire regimes. Both species are affected by competition; the Brush-tailed Phascogale is affected by competition from the introduced honey bee for nesting hollows (NSW NPWS 1999), and the Rufous Bettong faces competition from rabbits (DECCW 2012a).

The Spotted-tailed Quoll is threatened by habitat loss and fragmentation which reduces numbers of suitable den sites and prey (DECCW 2012b). The Spotted-tailed Quoll is also susceptible to inadvertent poisoning by poisons such as 1080 during wild dog and fox control programs and competition for food from introduced predators such as cats and foxes. There is anecdotal evidence that suggests that the Spotted-tailed Quoll is susceptible to poisoning by Cane Toads (*Bufo marinus*). This species is also known to feed on road kill where it is vulnerable to vehicle strike.

The Long-nosed Potoroo is threatened by habitat loss and fragmentation from land clearing for residential and agricultural development (DECCW 2012c). Geographical separation is also a major threat to the species where isolated populations face difficulties breeding (DECCW 2012). The Long-nosed Potoroo is vulnerable to predation by foxes, dogs and cats (Queensland Museum 2007) and the reduction of understory vegetation by grazing and fire. There is also the potential for this species to be adversely affected by the removal of top order predators such as wild dogs and dingoes from the resulting competition from increased numbers of wallabies and foxes.

All species of cave-roosting bats subject of this plan face similar threats predominantly from disturbance of roosting sites, habitat damage and loss, use of pesticides and herbicides (through reduction in invertebrate prey, or bioaccumulation of toxic substances), and from the introduction of exotic pathogens such as the White-nosed Fungus (DECCW 2012d, 2012e, 2013 and 2012f). Additional threats include predation by feral cats and foxes, and reduction of stream water quality.

3. Potential impacts and management approach

The following chapter provides a brief overview of the potential impacts to the threatened mammals with reference to the more detailed impact assessment presented in the biodiversity working paper. It describes the potential impacts to the species at specific locations along the upgrade and during the pre-construction, construction and post-construction (operational) stages of the project to provide context to the management approach. The mitigation approach presented in the EIS and documented in **Chapters 4** to **6** of the management plan target the predicted impacts.

3.1 Potential impacts associated with the project

3.1.1 Rufous Bettong

Potential impacts to the Rufous Betting are discussed in Section 4.3.2 (pp. 311-312) of the Biodiversity Assessment Working Paper (Roads and Maritime 2012). In summary this includes:

- Three broad locations where known populations of both species are affected by the project:
  - Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Section 1-2).
  - Pillar Valley to Harwood (Section 3 and 4) in the foot slopes of the Sommervale Range extending to intact and fragmented habitats on lower undulating lands near Bostock Road, Sommervale Road to Tyndale and Gulmarrad and upper Shark Creek.
  - Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

Potential impacts are associated with loss of habitat, in particular clearing of mature trees, ground-cover and logs as well as the barrier effect of the highway and potential isolation of habitat and populations. There is potential for increased predation pressure associated with displacement of individuals from home ranges, fragmentation and degradation of habitat adjoining the project and the effects on dispersal of individuals. These impacts would temporarily affect dispersal, foraging, sheltering and breeding events. The loss of habitat would also likely impact on the home range territory of a number of individuals, remove a percentage of the shelter and foraging resources for these animals and potentially disrupt multiple breeding seasons. The number of animals affected in relation to the size of local sub-populations or meta-populations is not known. The regional population potentially extends across most of the north coast region including multiple project upgrades as discussed and may be separated by barriers such as the Clarence and Richmond River, or existing Pacific Highway. A reduction in movements could also lead to potential separation of sub-populations and reduced viability. The severity of the impact on the regional population is low, as the species is widespread over a large portion of the bioregion.

The project would remove up to 443 hectares of open forest and woodland vegetation predicted as potential habitat for this species; this would include the loss of foraging resources and habitat connectivity. The overall reduction of habitat is a small proportion of the available potential habitat. Sub-populations are predicted to persist following construction of the project, and the species was recorded in cleared and modified habitats including forestry areas, and grazing land with small remnant patches suggesting some tolerance to disturbance. Measures to mitigate the barrier effect of the road have been considered in the design and placement of fauna crossing structures to maintain connectivity and fauna exclusion fencing.

3.1.2 Brush-tailed Phascogale

Impacts of the Brush-tailed Phascogale are discussed in Section 4.3.2 (pp. 311-312) of the Biodiversity Assessment Working Paper (Roads and Maritime 2012).

There are three broad locations where known populations are affected by the project:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Section 1-2).
- Pillar Valley to Harwood (Section 3 and 4) in the foot slopes of the Sommervale Range extending to intact and fragmented habitats on lower undulating lands near Bostock Road, Sommervale Road to Tyndale and Gulmarrad and upper Shark Creek.
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

Potential impacts are associated with loss of habitat, in particular those containing hollow bearing trees and the barrier effect of the highway as well as potential for increased predation associated with fragmentation and degradation of habitat adjoining the project. These impacts would temporarily affect dispersal, foraging, sheltering and breeding events. The severity of the impact on the regional populations is low, as the species is widespread over a large portion of the bioregion.

The project would remove up to 443 hectares of open forest and woodland vegetation; this would include the loss of foraging resources and habitat connectivity. The overall reduction of habitat is a small proportion of the available potential habitat. Sub-populations are considered to persist following construction of the project however there may be increased isolation of fragmented populations and the long-term viability of small populations may be impacted. The species is known to be resilient to some habitat disturbance and is known from modified habitats in agricultural areas indicting a degree of tolerance. Measures to mitigate the barrier effect of the road have been considered in the design and placement of fauna crossing structures to maintain connectivity.

3.1.3 Spotted-tailed Quoll

Impacts of the Spotted-tailed Quoll are discussed in Section 4.3.2 (p. 314) of the Biodiversity Assessment Working Paper (Roads and Maritime 2012).

Potential impacts for the species are associated with the loss of habitat including potential den sites, fragmentation and the barrier effect of the highway potentially leading to increased genetic isolation of sub-populations. The species is known to frequent roadsides feeding on road kill and where would be threatened by vehicle strike. The severity of the impact on the regional population is low as the species is very widespread over a large portion of the bioregion and there are considerable areas of potential habitat over private and conserved lands. Impacts to sub-populations may be more moderate and associated with fragmented and isolation. Large areas of habitat would remain in state forests and reserved habitats for the longer-terms viability of the regional population.

The species is very widespread throughout all areas and habitats of the North Coast Bioregion. There are no records of particular clusters near the project that would suggest an important population exists in a small area. However based on the habitats present, in particular the larger state forests and conservation reserves, two main areas exist which may represent important habitat for regional populations. These are the areas from Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections1 and 2) and Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7). These habitats are largely associated with the mature dry and moist sclerophyll forests on both sandy and clay soils. Large areas of habitat would remain in state forests and reserved habitats for the longer-terms viability of this species.

3.1.4 Long-nosed Potoroo

Impacts of the Long-nosed Potoroo are discussed in Section 4.3.2 (p. 315) of the Biodiversity Assessment Working Paper (Roads and Maritime 2012).

A population is known from Wardell Heath in Section 10 and associated with the wet and dry heath habitats on sandy soils, a Eucalypt canopy can be present or absent. Wardell Heath is a name referring to a large area of land containing a mosaic of heath, forest and swamp habitats positioned adjacent on the western side of the Richmond River near Wardell generally east and south of the project between chainage 148000 to 156000. Section 10 of the project would traverse around this habitat on the western side and not directly involve a loss of habitat for the Long-nosed Potoroo population in this location. Similar habitats on sandy soils with a Eucalypt canopy and heathy understorey also occur to the west of the alignment near chainage 146500 and 148000, while the species has not been confirmed in this location, it should be considered suitable habitat.

Potential indirect impacts to habitat may be associated with impacts on groundwater through construction potentially affecting the condition of the retained habitats. Groundwater impacts are considered to be minimal. There is the impact of the potential barrier effect on dispersal and movements of the species between 146500 and 148000. There is limited connectivity to similar habitats for these species across the North Coast Bioregion, which explains its relative isolation. The Richmond River is a barrier to the east and the only movement opportunities are to the north across a network of existing roads. Large areas of habitat would remain in the landscape within Wardell Heath for the longer-term viability of this species, however the highway will create a barrier to movements and connectivity to other populations to the west and north of Wardell.

Up to 10 hectares of wet and dry heath along the edges of the existing highway would be removed for the project, this provides potential habitat for this species, however there are no recent accounts of populations present near the highway.

3.1.5 Cave-roosting microbats

The loss of forest habitat, in particular swamp forest (149 hectares) and wetlands (13 hectares) would impact on the potential breeding habitat for prey species (invertebrates) and therefore potentially lead to reduction of populations associated with increased pressure on local populations. However comparable habitats are well represented throughout the locality and regional area and predation by bats would account for only a very small proportion of the prey availability. Therefore impacts on foraging habitat and prey abundance would result from the project, however, the overall magnitude of impact is small relative to the extent of insect breeding resources in the area.

Impacts on known roosting habitat or a roosting colony have not been identified and no artificial roost sites have been identified at this stage of the project despite targeted surveys. There is potential for these species to roost in culverts or bridges along the existing highway as well as tree hollows for some species (refer Schulz 1997) and Fairy Martin *(Hirundo ariel*) nests (Schulz 1998).

The project would remove about 948 hectares of habitat comprising a combination of wet and dry sclerophyll forest and heath which theoretically provides potential foraging, shelter and breeding habitat for the assessed insectivorous bat species. The effect of the removal of this habitat is to remove breeding and shelter opportunities for insect prey and hunting habitat for bats, potentially leading to a reduction in population size or range. Southern Myotis hunt over water bodies for small fish and invertebrates and may frequent the creek and wetland habitats. Impacts on foraging habitat for this species would result from the project however the overall magnitude of impact is relatively small.

3.2 Detailed design considerations

A number of factors would be addressed in the detailed design phase to minimise the impacts of the project. The factors to be considered which would be particularly relevant for the minimisation of impacts to threatened mammals include:

- Avoiding and minimising vegetation / habitat removal wherever possible.
- Consideration of water quality.
- Refinement of connectivity mitigation measures including the design and location of underpasses, overpasses, rope crossings and fauna exclusion fencing.

As a minimum the design of threatened mammal targeted crossing structures and permanent exclusion fencing would be based on the design principles outlined in the EIS and the process for managing threatened mammal connectivity requirements described in the Biodiversity Connectivity Strategy (Roads and Maritime 2011). This includes a comprehensive program to monitor the effectiveness of crossing structures and the inclusion of precautionary options. For example, given the possibility for threatened mammals to enter the road corridor over the life-time of the road, refinement of the location of the proposed the fauna exclusion fencing and crossing structures would be required (refer to **Section 4.3.2**). Refinement of the location of these measures would be informed by targeted fauna surveys (refer to **Section 4.3.1**).

In summary the objectives of the targeted threatened mammal surveys would be undertaken on all upgrade sections to:

- Review the proposed exclusion fencing locations and identify the need, extent and design of exclusion fencing.
- Identify the use of identified drainage structures by cave-roosting microbats, with a focus on use by threatened species and including any potential for breeding roosts to be impacted.

3.3 Mitigation and monitoring approach

A number of measures to mitigate and monitor the impact of the project on threatened mammals during construction and operation of the project were identified in the Biodiversity Assessment Working Paper (Roads and Maritime 2012) and are discussed in detail in this plan. In general these measures relate to:

- The production of project specific flora and fauna management plans.
- Exclusion zones to protect adjoining habitats during construction.
- Connectivity mitigation measures (arboreal crossing structures, widened medians, dedicated overpasses and underpasses and combined drainage / fauna crossing structures).
- Permanent fauna exclusion fencing to minimise road moralities and direct to crossing structures.
- Sensitive pre-clearing and clearing procedures to consider animal; welfare and translocation from clearing areas.
- Nest boxes for hollow-dependent fauna which may include compensatory habitat for roosting bats if encountered.
- Revegetation of suitable habitat along areas disturbed by construction including reuse of woody debris and bush rock.

3.4 Effectiveness of mitigation measures

A summary of the proposed threatened mammal mitigation measures and evaluation of their effectiveness based on past experience for other highway upgrades is described in **Table 3-1**. Specific mitigation measures were taken from the EIS (Chapter 10) Table 10-32.

Table 3-1. Mitigation measures and evaluation of their effectiveness

Issue	Mitigation measure	History of success	Effectiveness rating
Loss of habitat via the removal of vegetation including the removal of hollow bearing trees	• Identification of clearing limits and establishment of exclusion zones. • Pre-clearing and clearing procedures • Ethical Faunal handling procedures. • Reuse of woody debris and bushrock to re-establish habitat as required • Development and implementation of a next box management plan.	A standard procedure has been developed by Roads and Maritime and documented in the Biodiversity Guidelines for Construction (RTA 2011). The guidelines were developed in consultation with the NSW Office of Environment and Heritage (OEH), NSW Department of Primary Industries (DPI) (Fisheries), biodiversity specialists and Roads and Maritime staff including project managers, construction personnel and designers. Consultation was facilitated through a number of workshops carried out in 2009. These procedures have been developed using knowledge gained from a long history of upgrades on the Pacific highway and other road projects in NSW. Guidance regarding nest box installation and maintenance are provided in the Roads and Maritime Biodiversity Guidelines- Guide 8 Nest Boxes (RTA 2012). Nest boxes have been used on the Kempsey Bypass project specifically in relation to the Bush-tailed phascogale.	Moderate, monitor effectiveness and implement contingencies where appropriate.
Fragmentation of habitat and reduction in movement leading to a potential separation of populations.	• Construction of fauna crossing structures for ground-dwelling mammals. • Arboreal crossing structures and widened median for Brush-tailed Phascogale. • Nest boxes for Brush-tailed Phascogale. • Temporary and permanent fauna exclusion fencing installation. • Monitoring of fauna crossing structures.	Initial monitoring of the use of culverts for Rufous bettong crossing structures has been undertaken for the Glenugie Upgrade project. At the time of writing this plan the results of the monitoring were not published. Roads and Maritime also undertook a review of the use of fauna passage structures for a number of Pacific Highway projects in 2009. This review found that in general the Potoroo was using bridges, box culverts and purpose built fauna connectivity structures, the Quoll was using box culverts and purpose built fauna connectivity structures and the Brush-tailed phascogale was using cut and cover overpass structures. Bat passages were also recorded using several culverts in the Bulahdelah to Coolongolook upgrade project for passage. Although it should be noted that bats are not reliant upon underpasses for access to habitat areas. As noted above, nest boxes have been used on the Kempsey Bypass project specifically in relation to the Bush-tailed phascogale.	Moderate, monitor effectiveness and implement contingencies where appropriate.
Vehicle collisions on the upgraded highway.	• Installation of permanent fauna exclusion fencing. • Maintenance of fauna fences, gates and crossing structures.	Roads and Maritime routinely conducts maintenance on exclusion fencing along the Pacific Highway both as a standard procedure and in response to a breach in the fence or speight of fauna road kills. It has been standard practice on Pacific Highway projects for Roads and Maritime to identify fauna fencing locations in the project environmental impact assessment. Fauna fencing locations would then be refined further in detailed design and also post construction in cases where road fauna mortality has indicated a need for additional fencing. Examples include Tandys Lane Upgrade, Yelgun to Chinderah Upgrade, Bonville Deviation and Karuah to Bulahdelaha.	Moderate, monitor effectiveness and implement contingencies where appropriate.

Inadvertent poisoning from the use of herbicides and pesticides.	• Development and implementation of a herbicide and pesticide procedure in accordance with the Roads and Maritime Biodiversity guideline.	Roads and Maritime has developed standard weed management procedures that are implemented during construction and are reported as part of the FFMP. This includes pre-clearing weed surveys to identify noxious and environmental species and map their location for on-going monitoring and control during construction and operation. Monitoring noxious and environmental weeds is a routine procedure for road upgrades which has a long history of success in NSW.	Moderate, monitor against performance and implement weed management actions as required.
Introduction of predators	• Wild dogs, cats or fox control.	Roads and Maritime does not conduct wild dog and/or fox control and would engage with appropriate stakeholders to identify appropriate predator control actions.	Moderate, monitor and engage with relevant agencies regarding corrective actions required.
Disturbance of roost sites.	• Preclearance surveys of culverts and bridges prior to demolition.	Pre-clearance surveys are a routine procedure that has been implemented for a number of Pacific Highway projects to identify and protect fauna. Projects where the pre-clearance surveys have been implemented successfully includde the Tintembar to Ewingsdale, Sapphire to Woolgoolga, Coopernook to Herron Creek and Coopernook Bypass	Moderate, monitor effectiveness and implement contingencies where appropriate
Introduction of pathogens.	• Development and implementation of a pathogen management plan.	A guide for pathogen management (guide 7) is included in *Biodiversity Guidelines Protecting and managing biodiversity on RTA projects* (RTA 2011). This guide is a standard procedure that has been successfully implemented by Roads and Maritime for a number of Pacific Highway projects.	Moderate, monitor effectiveness and implement contingencies where appropriate
Decline in stream water quality.	• Water quality managed in accordance with procedures in the CEMP.	Roads and Maritime has successfully used water quality controls across a number of Pacific Highway projects. Procedures for water quality management on construction sites have been developed in accordance with the Blue Book principles and form part of the CEMP process. However as stated previously there has been no monitoring of the impacts of road run-off on the Pacific Highway in terms of impacts on frog habitat and populations. The threatened subject species are known to occur in locations adjacent to the existing highway suggesting some tolerance of road run-off impacts however this has not been tested.	Moderate, monitor success and implement corrective actions

3.5 Adaptive management approach

The management plan has been presented using an adaptive management approach based on firstly identifying specific goals for management, implementation of management actions followed by monitoring of the performance of these measures against the goals and identified thresholds. As a final step the monitoring would evaluate the effectiveness of the management measures using identified thresholds for performance and implementing corrective actions to improve mitigation where required.

To ensure the success of this approach the management goals presented in the plan are based on the following SMART principles:

- **S**pecific.
- **M**easurable.
- **A**chievable.
- **R**esults-based.
- **T**ime-based.

4. Pre-construction management measures

4.1 Potential impacts during pre-construction

- Location of infrastructure within ancillary facility sites may impact on mammal habitat, movements, foraging and behaviour.

4.2 Mitigation goals

- Completed designs for connectivity mitigation measures
- Confirmation of important habitats for threatened mammals prior to commencement of construction

4.3 Targeted surveys

Targeted surveys would be undertaken in the pre-construction phase to further inform the management plan by confirming the presence of threatened mammals, collect baseline population data, habitat quality information and identify ongoing monitoring locations for the threatened mammals detailed in this plan. This survey would be undertaken pre-construction within known and likely habitat and also focus near connectivity structure locations to inform on-going monitoring of use. Survey data would be used to inform the identification of fauna revegetation areas as outlined in project specific revegetation plans and refine the location of fauna exclusion fencing, fauna crossing structures and permanent monitoring sites (refer to **Section 5.3.7** and **Chapter 7**). The objectives of the targeted surveys would be to:

- Confirm threatened mammals presence and density at specific locations, which would be used to identify monitoring sites and for input into the mitigation monitoring program.
- Confirm or refine proposed connectivity structure and fauna fencing locations as outlined in the EIS and Chapter 5, which may include the need for additional structures, or movement of structures in the case of rope crossing structures.

For crossing structures, the location of threatened mammal populations from these targeted surveys would further inform the detailed design, particularly in relation to the types of revegetation and fauna furniture to be used to suit the target species.

Potential monitoring locations would focus on known and likely habitat areas identified adjacent to the project where the presence of threatened mammal species were confirmed in the EIS or where they were considered highly likely.

The targeted surveys would also identify and record data on control and reference sites. The location of the monitoring, control and reference sites would be reported in the first monitoring report.

All culverts and bridges to be removed from the existing highway would be surveyed prior to demolition to assess the presence of roosting microbats before any demolition activities take place (refer **Section 3.2 and 5.3.2**).

The timing and methods of the targeted surveys are described ion more details in chapter 7.

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4.4 Management measures

4.4.1 Detailed design of permanent fencing and crossing structures

The objective is to use the data gathered from the targeted survey to inform the detailed design with respect to the locations of permanent exclusion fencing and refine crossing structures types and locations. The location of fencing would be informed by the information collected during the targeted surveys and would be planned in the pre-construction phase with implementation during construction. The plan would provide detail on fence types and structures, and specific locations for fencing including fencing at crossing zones perpendicular to the construction corridor.

4.4.2 Identify habitat exclusion zones

An exclusion zone is a designated 'no-go' area that is clearly identified and appropriately fenced to prevent damage to native vegetation and fauna habitat. This procedure would be documented in the CEMP and project specific FFMP and conducted along the entire construction corridor for flora and fauna in general and would targeted exclusion of habitat fir threatened mammals.

Habitat exclusion zones and limits of clearing would include consideration of habitat trees, hollow bearing trees and important habitat for targeted species. The location of appropriate habitat exclusion zones would be identified from the targeted survey during pre-construction, with temporary fencing to be erected in the construction phase.

Identification of exclusion zones may be staged with a priority for early works sites and then remaining areas of the construction corridor. Survey personnel would be inducted to ensure they do not encroach outside the limits of clearing.

Construction related infrastructure would also be planned and sited within cleared or disturbed areas of the fenced ancillary sites, particularly keeping clear from water sources and known fauna movement areas.

4.5 Performance indicators and corrective actions

Table 4-1 summarises the pre-construction measures for threatened mammals that are to be completed prior to the commencement of construction.

Table 4-1 Performance indicators and corrective actions – pre-construction

Main goal	Mitigation / control measure	Monitoring/timing frequency	Performance thresholds	Corrective actions if deviation from performance criteria
Completed designs for connectivity mitigation measures	Conduct targeted survey and use data to refine locations of fauna exclusion fencing and connectivity structures where appropriate	Completed during detailed design and signed off prior to construction commencing	Designs not updated and complete before construction	Construction delayed and clearing works would not commence until exclusion zones have been approved as part of the CEMP.
Confirmation of important habitats for threatened mammals prior to commencement of construction	Conduct targeted survey and identify appropriate exclusion zones along the project corridor and ancillary sites.	Once only, event based, reported in the CEMO/FFMP for each project.	Exclusions zones identified and approved as part of the CEMP and FFMP for each project prior to construction being undertaken.	Construction delayed and clearing works would not commence until exclusion zones have been approved as part of the CEMP.

5. Construction management measures

5.1 Potential impacts during construction phase

- Removal of threatened mammal habitat including habitat trees and hollow bearing trees.
- Disturbance and degradation to adjoining threatened mammal habitat outside of construction corridor.
- Injuries or mortality of threatened mammals during vegetation clearing.
- Contamination or isolation of water supplies used by threatened mammals.
- Direct impacts to roosting bats in artificial structures

5.2 Mitigation goals

- No damage to threatened mammal habitat outside the project exclusion zones.
- Low number of injuries or mortality of threatened mammals as a result of vegetation clearance.
- Low number of injuries or mortality of roosting microbats from removal of culverts or bridges.
- No contamination or isolation of water supplies adjoining the project.
- Provide opportunity for daily movements of target species across the highway.
- Provide compensatory roost/shelter habitat for hollow-dependent fauna.

5.3 Management measures

5.3.1 Work method statements

Work method statements would be prepared for specific activities (eg clearing and grubbing) to ensure sound environmental practices have been implemented and to minimise the risk of environmental incidents or system failures, in accordance with the CEMP.

Work method statements would be prepared to address all construction threaten mammal management requirements in consultation with relevant agencies, Roads and Maritime and the relevant project environmental manager prior to the commencement of identified activities.

General responsibilities for environmental management would be outlined in the CEMP and FFMP.

The Roads and Maritime would finalise this threatened mammal management plan in consultation with DSEWPaC, DoPI and OEH. Following acceptance of the plan and staging priorities the Roads and Maritime, the construction contractor and the contractors ecologist engaged for the relevant project sections for these species would be responsible to oversee implementation of the plan for the construction related management measures.

5.3.2 Construction induction and training

Induction and training would be conducted with all contractors and other staff that would be working in the area of known and potential threatened mammal habitat. This training would identify the threatened mammals and their habitats, distribution and key threats, with all personnel shown pictures of the species. The importance of following the clearing, translocation and rehabilitation protocols would be made clear for any personnel that require access to the site.

5.3.3 Installation of habitat exclusion zones

Temporary fencing would be installed around exclusion zones to indicate the limits of clearing and to prevent threatened mammals from entering the construction corridor. Temporary fencing type would be selected in accordance with the *Roads and Maritime Biodiversity Guidelines – Guide 2 Exclusion Zones* (RTA 2011). The risk of threatened mammals being trapped, injured or isolated would be considered for fauna exclusion fencing designs and placement.

5.3.4 Pre-clearing surveys (threatened mammals)

Pre-clearing procedures would be outlined in the CEMP and project specific FFMP, and would be undertaken in accordance with *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011), in order to minimise impacts on flora and fauna.

In summary, prior to the commencement of clearing operations (pre-clearance), a licensed ecologist would identify all exclusion zones areas within the project where vegetation and habitat would be retained. The exclusion zones would be identified during the pre-clearing surveys. Threatened mamals identified within the clearing footprint would be relocated to similar habitat adjacent to the project. Release sites for threatened mammals would be identified prior to the commencement of clearing.

Clearing of vegetation and habitat features would be undertaken in a two stage process following the completion of pre-clearance surveys. Under scrubbing and the removal of non-habitat trees would be undertaken first. Habitat trees (including hollow-bearing trees) would be removed at least 24 hours after the removal of non-habitat trees, to enable resident hollow-dependent fauna to evacuate the tree prior to felling. An ecologist would be present to supervise the removal of each habitat tree. The ecologist would inspect each felled tree and record habitat/hollow characteristics and evidence of habituation. A wildlife carer would manage any injured or displaced fauna. The ecologist would relocate and release displaced fauna upon confirmation of the animal's health.

5.3.5 Pre-clearing surveys (roosting microbats)

All bridges and culverts anticipated to be removed or upgraded would be surveyed prior to construction to assess their suitability for microbat habitation and check for the presence of cave roosting microbats, including occupancy of any disused martin nests. Methods would involve inspecting each site for the presence of roosting microbats. Surveys would coincide with microbat breeding events to maximise detection of breeding use as well and would be targeted where possible for spring-summer to maximise chance of survival for released bats.

If microbats are identified, a staged exclusion involving the provision of alternative roosting habitat would take place. This involves roost watching prior to the evening flyout to identify when microbats have vacated the roost. A microbat experienced ecologist would inspect the roosts to confirm that no microbats are present. Once this has been confirmed, screening (bird proof netting of an appropriate diameter 10-15 millimetres) would be attached to the under sides of the structure to prevent returning microbats roosting in the structure. A one-wa flap design would be used for small cracks, fissures or lifting holes consistent with the procedures used on other Roads and Maritime projects.

Alternative habitat in the form of multichambered bat boxes or drill holes in concrete would be provided. Where roosting bats are to be removed from an existing bridge structure, the Roads and Maritime would engage in consultation with OEH prior to removal and plan to provide alternative artificial roosting habitat as part of the new bridge construction. This would be documented in a project specific Bat Management Plan and would include details of the artificial structures and monitoring procedures.

5.3.6 Clearing procedures

Clearing procedures would be outlined in the CEMP and project specific FFMP, and would be undertaken in accordance with *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011), in order to minimise impacts on flora and fauna.

An ecologist(s) would be present on site during all vegetation clearing and habitat removal activities to capture and relocate fauna that may be encountered. Identified habitat would be left for at least 24 hours after removing non-habitat vegetation to allow fauna to escape. If necessary, fauna may need to be trapped and relocated to pre-determined habitat identified for fauna release. The *NSW Code of Practice for Injured, Sick and Orphaned Fauna* (OEH 2011) would be followed for trapping and relocating threatened mammals (refer to **Appendix C**). Any injured, sick or orphaned fauna would be cared for by a licensed wildlife carer.

5.3.7 Permanent fauna exclusion fencing

Permanent fauna exclusion fencing would be installed at locations along the carriageway to prevent the movement of ground and arboreal mammals across the carriageway and to funnel mammal movements to a fauna crossing structure. As noted in **Section 4.3.2**, the targeted survey findings would assist in refining the fauna exclusion fencing locations outlined in the EIS. Design principles for fauna exclusion fencing are detailed in the Biodiversity Connectivity Strategy (Roads and Maritime 2012). For threatened mammals, specifically, this includes:

- Construction of fencing on both sides of the carriageway and generally extending at least 200 metres either side of a designated crossing structure.
- Continuous fencing with a 'return area' at their ends to guide animals back into habitat rather than across the carriageway.
- Perpendicular fencing in widened medians to direct fauna across the median and to ensure that fauna do not colonise habitat within the median, or turn back onto the road.
- Mesh size selected to prevent the target species from climbing through.
- Fence designed to prevent fauna from digging underneath, or passing through points where fencing crosses drainage lines.
- Arboreal mammal fences would need to be designed to prevent animals from climbing over, with the addition of a barrier in Sections 1-3 and 6-8 of the project for the Brush-tailed Phascogale.

5.3.8 Fauna connectivity structures

Fauna connectivity structures would be provided to maintain existing levels of landscape connectivity for threatened mammals likely to move between habitat areas on the eastern and western sides of the project. Connectivity structures for threatened ground and arboreal mammals include:

- Underpasses (bridges and culverts) – Rufous Bettong, Spotted-tailed Quoll, Long-nosed Potoroo
- Overpasses (land bridges) – Rufous Bettong, Spotted-tailed Quoll, Long-nosed Potoroo
- Canopy (rope) bridges – Brush-tailed Phascogale
- Widened medians - Rufous Bettong, Spotted-tailed Quoll, Long-nosed Potoroo. Brush-tailed Phascogale
- Fauna exclusion fencing – Rufous Bettong, Spotted-tailed Quoll, Long-nosed Potoroo, Brush-tailed Phascogale.

Fauna connectivity structures and design principles, locations and target species are proposed in the Biodiversity Connectivity Strategy (Roads and Maritime 2012). Both dedicated and combined fauna connectivity structures which have been designed specifically for threatened mammals are summarised in
Table 5-1 below. This table does not include structures targeted for the koala or threatened gliders which are outlined in the Koala management plan and Threatened glider management plan. The design principles for fauna connectivity structures were developed in consultation with OEH and designed specifically for this project as detailed in the EIS.

Fauna furniture would be placed within dedicated underpasses, including interconnecting logs to provide a dry passage for threatened mammals whilst also providing refuge from predators and refuge poles outside and within the culvert to provide refuge from predators.

Table 5-1 Fauna crossing structures for threatened mammals at concept design

Project Section	Chainage	Connectivity structure	Functionality	Target species	Adjacent habitat/s
1	1.500	Rope crossing (length 65 m)	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	-
1	2.100	RCBC (box culvert 3 x 2.4 x 41m))	Underpass – combined	Small-medium mammals	SEPP14 Wetland and Wedding Bells SF, link with Coffs Regional Park (Zone 7a)
1	3.545	Bridge (90.5 x 10.5m)	Underpass – combined	Small-large mammals	-
1	4.010	Bridge (300.5 x 10.5m)	Underpass – combined	Rufous Bettong, small-large mammals	-
1	4.685	Bridge (75.5 x 10.5)	Underpass – combined	Small-medium mammals	-
1	6.780	RCBC (box culvert 3 x 3 x 3 x 48m)	Underpass – dedicated	Rufous Bettong, Spotted-tailed Quoll	-
1	7.285	RCBC (box culvert 3 x 3 x 65m)	Underpass – combined	Rufous Bettong, Spotted tailed Quoll	-
1	8.510	RCBC (box culvert 3 x3 x70m)	Underpass – dedicated	Rufous Bettong, Spotted-tailed Quoll	-
1	10.745	RCBC (box culvert 3 x 3 x 55m)	Underpass – combined	Rufous Bettong, Spotted-tailed Quoll	-
1	11.785	RCBC box culvert 3 x 3 x 71m) linked with fauna fencing	Underpass – combined	-	-
1	12.325	RCBC (box culvert 3 x 3 x 41m) linked with fauna fencing	Underpass – combined	Spotted-tailed Quoll	Dirty Creek Range to Newfound land SF and Yuraygir SRA
1	12.750	Rope crossing (length 65m)	Dedicated fauna crossing for arboreal mammals	Squirrel Glider, Yellow-bellied Glider and Brush-tailed Phascogale	Dirty Creek Range to Newfound land SF and Yuraygir SRA
1	12.885	RCBC box culvert 3 x 3 x 43m) linked with fauna fencing	Underpass – combined	Rufous Bettong, Spotted-tailed Quoll, Common Planigale	Dirty Creek Range to Newfound land SF and Yuraygir SRA
1	13.315	RCBC (box culvert 3 x 3 x 25m)	Underpass – combined	Rufous Bettong, Spotted-tailed Quoll, Common Planigale	Dirty Creek Range to Newfound land SF and Yuraygir SRA
1	13.835	RCBC box culvert 3 x 3 x 68m) linked with fauna fencing	Underpass – combined	Rufous Bettong, Spotted-tailed Quoll, Common Planigale	Dirty Creek Range to Newfound land SF and Yuraygir SRA
1	14.280	RCBC (box culvert 3 x 3 x 68m)	Underpass – combined	-	-
2	17.020	Rope crossing	Dedicated fauna crossing for arboreal mammals	Squirrel Glider, Yellow-bellied Glider and Brush-tailed Phascogale	Dirty Creek Range to Newfound land SF and Yuraygir SRA
2	20.650	RCBC (box culvert 3 x 2.4 x 48m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Yuraygir NP Yuraygir SCA and Wells Crossing Flora Reserve
2	20.718	Bridge (50.5 x 11m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Yuraygir NP, Yuraygir SCA and Wells Crossing Flora Reserve, Major Fish Habitat
2	20.880	RCBC (box culvert 3 x 2.4 x 43)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Yuraygir NP, Yuraygir SCA and Wells Crossing Flora Reserve
2	21.290	RCBC (box culvert 3 x 3 x 50m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Yuraygir NP, Yuraygir SCA and Wells Crossing Flora Reserve

Project Section	Chainage	Connectivity structure	Functionality	Target species	Adjacent habitat/s
2	22.373	Bridge (60.5 x 11m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Wells Crossing Flora Reserve, Major Fish Habitat
2	23.125	RCBC (box culvert 3 x 2.4 X 22m)	Underpass – dedicated	Rufous Bettong, Brush-tailed Phascogale	Wells Crossing Flora Reserve
2	24.575	RCBC (box culvert 3 x 2.4 X 46m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Glenugie State Forest
2	25.950	RCBC (box culvert 3 x 2.4 x 45m) linked with fauna fencing	Underpass – dedicated	-	-
2	27.420	RCBC (box culvert 3.6 x 2.6 x 104m)	Underpass – combined	Rufous Bettong, Brush-tailed Phascogale	Glenugie State Forest
3	35.230	RCBC (box culvert 2.5 x 2.4 65m) linked with fauna fencing from 35000 to 80200	Underpass – combined	Rufous Bettong	Glenugie State Forest
3	36.398	Bridge (75.5 11 to 16.1m)	Underpass – combined	Rufous Bettong	Glenugie Creek and Pheasant Creek
3	37.320	RCBC (box culvert 2.4 x 2.4 x 69m) linked with fauna fencing 35000 to 80200	Underpass – combined	Rufous Bettong	Glenugie Creek and Pheasant Creek
3	39.690	RCBC (box culvert 3.0 1.2 x 11m) linked with fauna fencing from 35000 to 80200	Underpass – combined	Rufous Bettong	-
3	42.541	Bridge (135.5 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Coldstream wetlands
3	43.121	Bridge (315.5 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Coldstream wetlands
3	43.906	Bridge (180.5 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Coldstream wetlands
3	46.074	Bridge (100.6 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Coldstream wetlands to Yuraygir NP
3	46.344	Bridge ((100.6 x 10.5m NB and 11.9m SB))	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Coldstream wetlands to Yuraygir NP
3	46.666	Bridge (75.5 x 10.5m NB and 11.9m SB)	Underpass – combined (Emu)	Medium to large mammals	Coldstream wetlands to Yuraygir NP
3	47.662	Bridge (75.5 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	-
3	48.100	Rope crossing(length 65m0	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Dry open sclerophyll forest on sand
3	49.265	Bridge (120x 10.5m NB and 11.6 SB)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP
3	50.299	Bridge (45 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP
3	50.500	Rope crossing (length 65m)	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Dry open sclerophyll forest on sand
3	51.430	RCBC (box culvert 2.4 x 3.6 x 62m) linked with fauna fencing from 35000 to 80199	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP

Project Section	Chainage	Connectivity structure	Functionality	Target species	Adjacent habitat/s
3	52.438	Bridge	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP
3	52.605	RCBC (box culvert 3.6 x 3.6 x 63m) linked with fauna fencing	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Chaffin Swamp to Chaffin Hill
3	53.710	RCBC (box culvert 3.6 x 3.6 x 63m) linked with fauna fencing from 35000 to 80199	Underpass – combined (Emu)	-	Chaffin Swamp to Chaffin Hill
3	53.850	Rope crossing (length 65m)	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Dry open sclerophyll forest on sand
3	54.706	Bridge (90 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP
3	57.027	Bridge (88 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong,	Clarence floodplain wetlands to Yuraygir NP
3	58.639	Bridge (75.5 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong, Brush-tailed Phascogale	Clarence floodplain wetlands to Yuraygir NP
3	59.285	Arch (5.5 m in height and 60m in length)	Dedicated (Emu)	Medium to large mammals including Rufous Bettong, Brush-tailed Phascogale	Clarence floodplain wetlands to Yuraygir NP
3	60.815	Arch (5.5 m in height and 60m in length)	Dedicated (Emu)	Medium to large mammals including Rufous Bettong, Brush-tailed Phascogale	Clarence floodplain wetlands to Yuraygir NP
3	64.505	Arch (5.5 m in height and 60m in length)	Combined (Emu)	Medium to large mammals including Rufous Bettong, Brush-tailed Phascogale	Clarence floodplain wetlands to Yuraygir NP
3	66.190	Arch 4m in height and 60m in length	Dedicated (Emu)	Medium to large mammals including Rufous Bettong	Clarence floodplain wetlands to Yuraygir NP
4	70.455	Bridge (18 x 11m, 12.5m, 8m)	Underpass – combined (Emu)	-	-
4	74.755	Bridge (448.6 x 10.5m)	Underpass – combined (Emu)	Medium to large mammals including Rufous Bettong	-
4	75.565	RCBC (box culvert 2.4 x 3.6 x 59m) linked with fauna fencing from 35000 to 80200	Underpass – combined	Small to medium mammals	-
4	75.880	Rope crossing (length	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Local corridor
4	76.450	RCBC (box culvert 2.4 x 2.4 55m))	Underpass – combined	Small to medium mammals	-
5	83.100	Bridge(30 x 15.8m NB and 12.8m SB)	Underpass – combined	Small to medium mammals	Yaegl Nature Reserve
5	93.990	Bridge(216.6 x 10.5m)	Underpass – combined		Major fish habitat
6	99.730	RCBC (box culvert 3.0 x 2.4 x 44m)	Underpass – dedicated	Small to medium mammals	Bundjalung NP and Mororo State Forest
6	100.640	RCBC (box culvert 2.4 x 1.8 x 71m) linked with fauna fencing from Fencing from 97900 to 101300	Underpass – combined	Small to medium mammals	Bundjalung NP and Mororo State Forest

Project Section	Chainage	Connectivity structure	Functionality	Target species	Adjacent habitat/s
6	101.100	RCBC (box culvert 3.0 x 2.4 x 38m) linked with fauna fencing	Underpass – dedicated	-	-
6	101.541	Bridge(132 x 10.5m)	Underpass – combined	Small to medium mammals	Local corridor connects Bundjalung NP
7	113.920	Bridge(15 x 11m)	Underpass – combined	-	-
7	115.272	Bridge (88 x 10.5m)	Underpass – combined	Small to medium mammals	Double Duke SF to Tabbimoble Swamp NR
7	116.400	Rope crossing (length 65 m)	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Double Duke SF to Tabbimoble Swamp NR
7	118.828	Land bridge (bridge 72.6 x 12.2m) with fauna fencing 111600 to 128400	Overpass – dedicated	Spotted-tailed Quoll, Brush-tailed Phascogale (small, medium & large mammals)	Double Duke SF to Tabbimoble Swamp NR
7	122.550	RCBC (box culvert 3 x 2.4 x 50m) linked with fauna fencing from 111600 to 128400	Underpass – combined	Small to medium mammals	Local corridor
7	123.590	RCBC (box culvert 3 x 2.4 x55m) linked with fauna fencing from 111600 to 128399	Underpass – combined	Small to medium mammals	Local corridor and key fish habitat
8	130.107	Bridge	Underpass – combined	-	Floodplain grasslands
9	138.430	RCBC (box culvert 1.2 x 1.2 x 85m) linked with fauna fencing from 137800 to 141000	Underpass – dedicated	Small mammals	Broadwater National Park
9	138.796	Land bridge (bridge 90.4 x 12.2m) with fauna fencing from 137800 to 141000	Overpass – dedicated	Small to large mammals	Broadwater National Park
9	139.440	RCBC (culvert)	Underpass – dedicated	Small mammals	Broadwater National Park
9	139.918	Land bridge (bridge 80.3 x 12.2m) with fauna fencing from 137800 to 141000	Overpass – dedicated	Small to large mammals	Broadwater National Park
9	140.620	Rope crossing	Dedicated fauna crossing for arboreal mammals	Brush-tailed Phascogale	Broadwater National Park
9	143.790	RCBC (box culvert 3.6 x 1.2 x 52m) with fauna fencing from142800 to 145119	Underpass – combined	Small to medium mammals	Local corridor connects Broadwater National Park to floodplain habitats
9	144.280	RCBC (box culvert 3 x 3 m linked with fauna fencing	Dedicated structure added for koala, however potential for other threatened fauna including Brush-tailed Phascogale	Brush-tailed Phascogale	Local corridor connects Broadwater National Park to floodplain habitats
9	144.700	RCBC (box culvert 3 x 3 x 48 m) linked with fauna fencing	Dedicated structure added for koala, however potential for other threatened mammals	Brush-tailed Phascogale	Local corridor connects Broadwater National Park to floodplain habitats
10	145.106	Bridge (viaduct 75.5 x 10.5m NB and 75.5 x 10.5-12.5m SB)	Underpass – combined	-	Floodplain grasslands
10	145.287	Bridge (789.9 x 11.5m)	Underpass – combined	-	Floodplain grasslands
10	146.360	RCBC box culvert 3 x 3 x 44m) Fence for koalas from 146100 to 159700	Underpass – combined	Small to large mammals	Regional link across Richmond River, CC assemblage. Links two key habitats
10	146.620	RCBC (box culvert 3 x 3 x	Dedicated structure added	Long-nosed Potoroo,	Regional link across

Project Section	Chainage	Connectivity structure	Functionality	Target species	Adjacent habitat/s
		55m)	for koala, however within the range and predicted habitat of the Long-nosed Potoroo	Brush-tailed Phascogale	Richmond River, CC assemblage. Links two key habitats
10	149.227	Wardell Viaduct 4 (twin bridges 18.0 x 11.0m)	Underpass – combined	-	Regional link across Richmond River, CC assemblage. Links two key habitats
10	150.030	RCBC (box culvert 3 x 1.5 x46m) Fence for koalas from 146100 to 159700	Underpass – combined	Small to medium mammals	Fish habitat waterways. Links two regional corridors
10	150.520	RCBC (box culvert 2.4 x 1.5 x42m) Fence for koalas from 146100 to 159700	Underpass – combined	Small to medium mammals	Fish habitat waterways. Links two regional corridors
10	150.600	RCBC (box culvert 3.6 x 1.62 x 42m) Fence for koalas from 146100 to 159700	Underpass – combined	Small to medium mammals	Fish habitat waterways. Links two regional corridors
10	151.933	Wardell Viaduct 6 (twin bridges 18.0 x 11.0m)	Underpass – combined	-	Floodplain grasslands
10	155.409	Bridge	Underpass – combined	-	-
10	156.006	Land bridge (bridge 62.0 x 12.2m)	Overpass – dedicated	Long-nosed Potoroo	Wardell Heath
10	156.305	RCBC (box culvert 3.3 x 1.2 x 52m) fence for koalas from 146100 to 159700	Underpass – combined	Long-nosed Potoroo	Wardell Heath
10	156.955	RCBC (culvert 1.8 x 1.2 x 53m) Fence for koalas from 146100 to 159700	Underpass – combined	Long-nosed Potoroo	Wardell Heath
10	157.605	RCBC (culvert 4.2 x 2.1 x 27m) Fence for koalas from 146100 to 159700	Underpass – combined	-	-
10	157.655	RCBC (culvert 3.6 x 1.8 x 59m) Fence for koalas from 146100 to 159700	Underpass – combined	-	-
10	157.825	Land bridge (17.5 x13 - 13.5m NB, 14.8-15.6m SB)	Overpass – combined	Small to medium mammals	-
10	158.850	RCBC (box culvert 3.6 x 1.8 x 25m)	Underpass – combined	Small to medium mammals	Local corridor connects Richmond River to Uralba Nature Reserve
11	164.650	Land bridge (221.9 x 12.5m)	Overpass – combined	Small to medium mammals	Local riparian corridor

5.3.9 Habitat revegetation

A habitat revegetation plan would be developed for each project that includes details of revegetation of native fauna habitats in areas disturbed during construction. The plan would be implemented as part of construction and would provide specific details for the revegetation in areas disturbed during construction and outside of fauna exclusion fencing. The plan would include revegetation around the approaches to connectivity structures considering the habitat requirements of the target species. The plan would also detail how maintenance of the revegetation would occur to ensure success of the landscape design and revegetation plantings.

Disturbed known and potential habitat areas within the project would be revegetated progressively through and at the end of the construction. The exact location(s) of revegetation areas has yet to be identified. Details on monitoring the performance of the revegetation, as well as, corrective actions to be implemented in instances of change from performance measures are provided in Chapter 7.

Revegetation around dedicated overpasses (e.g. Tabbimoble Nature Reserve Fauna Bridge, Broadwater National Park Fauna Bridges 1 and 2 and north and south Wardell Fauna Bridge) would be planted with native species consistent with that of the adjacent habitat (while complying with the Koala management plan and Threatened glider management plan) to provide habitat linkage to the structures. Appropriate species would also be considered in the revegetation of riparian corridors impacted by construction of combined underpasses (i.e. culverts and bridges).

Strategic revegetation would be undertaken to enhance connectivity through revegetation of lands within the road reserve and completed ancillary areas (where owned by Roads and Maritime). Priority for this road reserve revegetation should be given to:

- Local or regional fauna corridors, SEPP 14 wetlands and environmental protection zones. particularly where these might provide seasonal foraging resources.
- Habitat for important populations.
- Road kill hotspots.
- Cleared landscapes with limited connectivity, aiming to link current isolated patches with potential habitat for threatened mammals.
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- Specific locations identified in the EIS and supplementary biodiversity assessments would be targeted in revegetation works and includes ancillary areas where these are owned by Roads and Maritime and occur adjacent to a connectivity structure, for example Section 3 (site 2).

5.3.10 Hydrology and water quality

The project has the potential to change the hydrological functioning of the adjacent habitat, which may have impacts on the populations of threatened of mammals in the area. The principle objective of the drainage designs was to maintain current waterway and drainage flows that mimic the existing conditions as closely as possible.

Procedures including sediment and erosion control measures would be implemented to maintain water quality during construction, which would be included in the CEMP. These measures would be important in maintaining the current condition of threatened mammal habitat and to ensure water supplies have not been contaminated as a result of construction.

Water quality monitoring, particularly following rainfall events, would identify if the hydrology and water quality has been adversely impacted by the project.

5.3.11 Nest boxes

Nest boxes would be installed to compensate for the loss of hollow-bearing trees from the project. Nest boxes would be installed as compensation for loss of hollows for the Brush-tailed Phascogale. Installation and maintenance would be in accordance with the *Guide 8: Nest Boxes of the Roads and Maritime Biodiversity Guidelines* (RTA 2011).

The number and type of nest boxes required would be determined during the pre-clearance surveys based on the number, quality and size of the hollows that would be removed and the target species inhabiting the area (refer to **Section 4.3.1**). Following this a Nest Box Management Plan would be prepared for each project section detailing specifications for nest box dimensions, installation requirements, locations of nest boxes and ongoing monitoring and maintenance.

Seventy per cent (70%) of the nominated nest boxes would be installed prior to or during the clearing works with the objective of providing temporal refuge habitat for those hollow dependant fauna displaced during clearing operations. The remaining 30 per cent (30%) of nest boxes would be installed once a final tally of functional trees hollows has been compiled and reviewed as a result of the data collected during the clearing supervision. Occupancy rates of tree hollows during the clearing supervision would also facilitate the final number and types of nest boxes being installed.

5.4 Performance thresholds and corrective actions

Table 5-2 summarises the construction measures for threatened mammals and corrective actions if the measure deviates from the performance criteria.

- No damage to threatened mammal habitat outside the project exclusion zones.
- Low number of injuries or mortality of threatened mammals as a result of vegetation clearance.
- Low number of injuries or mortality of roosting microbats from removal of culverts or bridges.
- No contamination or isolation of water supplies adjoining the project.

Table 5-2 Performance indicators and corrective actions – construction

Mitigation goals	Mitigation / control measure	Monitoring/timing frequency	Performance thresholds	Corrective actions if deviation from performance criteria
No damage to threatened mammal habitat outside the project exclusion zones.	Exclusion zones fenced off and clearly marked. Contractors educated on the use of exclusion zones Fencing monitored with breaches repaired.	Audit fencing integrity prior to commencement of construction and during. Monthly monitoring of exclusion fence and protection zones as part of FFMP.	A single breach in exclusion zone/fencing by construction vehicle or unauthorised construction activities during construction.	Stop construction in the area of the breach until exclusion fencing has been repaired. Investigate why breach in fencing occurred and implement corrective actions as required to prevent reoccurrence. Supplementary revegetation of disturbed habitat and monitor recovery for period of 12 months.
Low number of injuries or mortality of threatened mammals as a result of vegetation clearance.	Temporary fencing to be erected prior to vegetation clearance. Pre-clearing and clearing procedures conducted as per protocol outlined in the FFMP.	Weekly fauna incident log to be maintained as per FFMP during clearing works. Daily exclusion fence monitoring.	A single threatened mammal species injured or killed during vegetation clearance.	Stop construction and review exclusion fence strategy and traffic control procedures as appropriate. Updated strategy as required. Review the clearing procedures and approach between ecologists and contractor and modify the techniques if found to be ineffective
Low number of injuries or mortality of roosting microbats removal of culverts or bridges.	Pre-clearing inspection of all artificial structures that will require removal for construction Where bats are encountered prepare a project specific Bat Management Plan that includes methods for removal of bats and provision of alternate roost structures, and monitoring	Event based monitoring, completed as part of pre-clearing and reporting in the CEMP compliance register. Bat management Plan prepared and implemented prior to removal of structure.	A single injury or mortality of a roosting microbat during culvert or bridge removal.	Stop construction and review the Bat Management Plan procedures for blocking roosts and removal of bats .
No contamination or isolation of water supplies.	Implement water quality procedures from the CEMP.	Weekly and event based monitoring of water quality and erosion controls.	No notable change in water quality as per CEMP requirements.	Review CEMP water management procedures as necessary.
Provide opportunity for daily movements of target fauna across the highway	Installation of combined and dedicated connectivity structures and exclusion fencing as per detailed design.	Monitoring of structures as per monitoring protocol	Ensure connectivity structures have been built in accordance with EIS/concept design principles	Upgrade connectivity structures as required.
Provide compensatory roost/shelter habitat for target hollow-dependent fauna	Prepare and implement a Nest Box Management Plan for each project Installation of 70% of the nest boxes prior to construction commencing	Monitoring of nest boxes as per monitoring protocol (Chapter 7). Audit of outcomes prior to construction	The appropriate number a type of nest boxes as per plan not installed prior to construction	Review procedure and rectify, halt construction until next boxes are erected.

6. Operational management measures

6.1 Potential impacts during operational phase

- Barrier to access of important habitat for life-cycle events
- Reduced dispersal ability and genetic isolation of sub-populations
- Direct mortality of threatened mammal from vehicle collisions.
- Degradation of adjacent habitats due to edge effect.

6.2 Mitigation goals

- Maintain habitat revegetation until evidence of successful cover and diversity
- Maintain fauna exclusion fencing and connectivity structures for the life of the project
- Maintain nest boxes for a period of eight years post-construction
- Contribute to regional predator control where predators are found to be using connectivity structures.

6.3 Management measures

6.3.1 Maintenance of habitat revegetation

A maintenance regime for revegetation areas would be incorporated into the project specific revegetation plan for each staged section and would be undertaken following construction in any areas within the road corridor that are adjacent to identified important threatened mammal habitats This may include revegetation adjacent to fauna crossing locations to restore connectivity within the road corridor to minimise edge effects to threatened mammals habitat that was not impacted by the project.

Consideration of the threatened mammal species located adjacent to revegetation areas would be required to ensure suitable plant species are used to revegetate these areas suited to the threatened mammal species. Specific suitable plants targeted at threatened mammals would be provided in the revegetation plan. The plan would also detail an appropriate the maintenance schedule for revegetation areas adjacent to threatened mammal habitat and fauna crossing structures.

6.3.2 Maintenance of fauna exclusion fencing and fauna crossing structures

The Roads and Maritime would conduct periodic monitoring and maintenance of fauna crossing structures and fauna exclusion fencing. The program would include inspections of the structures as part of the standard maintenance requirements along the highway for stability and damage for the life of the project and replacement where necessary or removal of debris where this is blocking the structure. Monitoring would also be conducted in response to observations and reports of fauna road kills in the vicinity of the crossing structures. Where roadkill hotspots are identified for targeted species and fencing is not in place the Roads and Maritime would install additional exclusion fencing as required.

To minimise the risk of rope bridges falling onto the road, poles suspending the ladder would be made from treated timber. Rope would be inspected periodically for signs of decay or weakening, and replaced where necessary for the life of the project.

6.3.3 Maintenance of nest boxes

The Ecological Monitoring Program outlines a consistent approach to the monitoring and maintenance of nest boxes. Monitoring would be required to determine the usage of nest boxes by the target species and identification of maintenance requirements. Monitoring requirements for next boxes is outlined in the Ecological Monitoring Program as detailed in **Section 7.6**.

As outlined in the Ecological Monitoring Program, during each monitoring event, a visual inspection of each nest box would be conducted to collect data such as occupancy, evidence of use by targeted species, pest species use, condition of nest boxes and maintenance requirements (such as changing the aspect of a nest box to address thermoregulatory considerations) and other general features such changes to the surrounding vegetation, weather conditions etc.

Factors that would be considered as part of the maintenance requirements for nest boxes include:

- The need to remove exotic pests species such as Common Mynas, Common Starling and European Bees.
- Replacement of fallen, damaged or degraded nest boxes.
- Repositioning, re-erection or relocation of dysfunctional nest boxes.
- Checking each box is not holding water or leaking.
- Removing excess nesting material as this may impede access over time.

6.3.4 Predator control

Predators can exploit the channelling function of fauna fencing by hunting near the entrance to a crossing structure such as an underpass or overpass (Harris *et al.* 2010). Should monitoring demonstrate wild dogs, cats or foxes to be predating on threatened mammals or inhibiting mammal movement through the crossing structures, the Roads and Maritime would engage with the Northern Rivers Catchment Management Authority, OEH (Parks and Wildlife Grafton), and Rural Lands Protection Board (North East) and adjacent landowners to identify and implement strategies to reduce this predation risk.

6.4 Performance measures and corrective actions

Table 6-1 summarises the operational environmental planning measures for threaten mammals and corrective actions if the measure deviates from the performance criteria.

- Maintain nest boxes for a period of ten years post-construction
- Contribute to regional predator control where predators are found to be using connectivity structures.

Table 6-1 Performance indicators and corrective actions – operation

Mitigation goal	Mitigation / control measure	Monitoring/timing frequency	Performance thresholds	Corrective actions if deviation from performance criteria
Maintain habitat revegetation until evidence of successful cover	Revegetation plan prepared for each section to target on revegetation along areas disturbed by construction Weed control in revegetation areas Replacement plantings	As per revegetation plan, monitor plant progress and weed cover	As per revegetation plan	Modify weed control technique or frequency Replacement plantings
Maintain fauna exclusion fencing and connectivity structures for the life of the project	Maintenance of fauna exclusion fencing connectivity structures as part of routine highway maintenance to remove debris and replace damaged rope crossings Monitor road kill as part of the routine road maintenance and repair broken exclusion fencing or install new fencing where required .	Regular monitoring as part of the Roads and Maritime routine highway maintenance program	Single roadkill of target threatened species reported would trigger maintenance check within 5 days Structure reported as damaged repair within 5 days	Find and repair damaged fence or structure Install new fencing where required
Monitor and maintain nest boxes for a period of 8 years from installation	Prepare project specific next box management plan Numbers and types next boxes determined by pre-clearance surveys for each project and documented in the NBMP Maintenance of damaged or degraded nest boxes as per NBMP Removal of pest species as per NBMP	Monitoring as per NBMP, likely biannual on alternate years	To be documented in the NBMP and include triggers for maintenance requirements, pest occupancy and usage rates for targeted threatened species, in tis case the Brush-tailed Phascogale	Replace or repair damaged or fallen boxes Remove pest species where required above threshold
Contribute to regional predator control where predators are found using connectivity structures	Provision of fauna crossing structures and fauna exclusion fences for threatened mammal movements	As per monitoring program described in Chapter 7	As per monitoring program described in Chapter 7 and associated with threshold number of predators recorded	Meet with regional pest control stakeholders and contribute to pest control program where reasonable and feasible

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7. Monitoring program

Monitoring would be undertaken to confirm the effectiveness of mitigation measures for threatened mammals. The monitoring program would use a BACI approach (Before versus After / Control versus Impact) comparing before and after data with impact versus control sites. Monitoring would focus on areas of known and potential habitat for the target species.

7.1 Objectives

Monitoring would be conducted until such time as the mitigation measures have been proven to be effective over three consecutive monitoring periods. The monitoring data would aim to provide robust information to draw sound conclusions around the effectiveness of mitigation measures for the target species and inform adaptive management actions. The objective of the monitoring and adaptive management program is to evaluate the success of mitigation measures against performance indicators and apply corrective management actions where poor performance is detected.

The monitoring program and methods, including impact and control site selection, may be subject to modification and refinement during the course of the program and would be dependent on the on-going results, access to monitoring sites or outcomes of the adaptive management actions.

7.2 Population densities

7.2.1 Monitoring goals

The goals of the population density surveys focus on detecting any change in density between impact and control site and determining if that change can be attributed to poor performance of crossing structures, which is addressed in a separate monitoring method. The specific monitoring goals are to:

- No significant change in threatened mammal population densities adjacent to the project at mitigated sites.

The monitoring program focuses on the Brush-tailed Phascogale, Rufous Bettong, Spotted-tailed Quoll and Long-nosed Potoroo. Cave-roosting bats were not identified in the EIS and further surveys are targeted during pre-clearing as described in Chapter 4. If cave-roosting bats are identified from the pre-clearance surveys, additional monitoring of bats may occur and would be documented in a project specific Bat Management Plan to be prepared. Monitoring may include use of alternative roost structures.

7.2.2 Selection of monitoring locations

The results of the targeted surveys for the threatened mammals would confirm the presence and densities of populations and finalise the impact and control/reference sites. The location of monitoring sites will be dependent on access to property. The surveys are designed to target habitats and locations reported in the EIS with the aim of establishing a set of monitoring sites that meet the following criteria:

- Impact sites (these would be mitigated sites such as near dedicated and combined crossing structures within 200 metres of the road edge and where possible on both sides of the road).
- Control sites (these would be unmitigated sites within 200 metres of the road edge on both sides of the road and at least 5 km from an impact site to account for home range areas).
- Reference sites (>500 metres from the project and greater than 5 km from impact sites to account for home range sizes). Reference sites for Spotted-tailed Quoll would need to be investigated for availability and require a suitable distance from impact sites to account for the large home-range of the species which may be more than 5 km.

It is envisaged that monitoring of the target species would adopt a whole of project approach by sampling populations of suitable density to provide sufficient data for analysis. In this way sites may be selected across multiple upgrade sections only where populations are detected. The total number of impact and control sites would therefore be analysed across the whole project as a single monitoring program for each species and not per upgrade section.

The location of reference sites would depend on ongoing consultation between Roads and Maritime, landowners and stakeholders which may include state forest, conservation reserves, private forested land or offset sites. The program would aim to ensure that control and reference sites are in the same habitat type as impact sites, this may be stratified by vegetation association (biometric vegetation types) and consider soil types, elevation, slope and aspect, however as these strata may restrict the program, stratification may be on broader habitat types, such as dry sclerophyll forest.

7.2.3 Timing and methods

Surveys would be conducted during pre-construction, construction and post-construction and aim to sample peak activity times of the target species. Biannual surveys are required for each species to capture the breeding and dispersal periods as described in Table 7-1. It would be optimum to conduct two surveys as the baseline prior to construction and then continue with biannual surveys during construction and operation for a period of five years from the baseline survey.

The survey methodology to be used would be based on DSEWPaC '*Survey guidelines for Australia's threatened mammals*' (DEWSEPaC 2011) and the NSW (former) Department of Environment and Conservation '*Threatened Species Survey and Assessment: Guidelines for developments and activities*' (DEC 2004).

Table 7-1 Threatened mammal survey methods

Target species	Timing	Method
Rufous Bettong	Autumn/Winter and Summer	Camera Survey 600 x 600 metre grid with camera traps set at every 100 metre interval (n=36) Traps stations are baited with a mixture of rolled oats, peanut butter, vanilla essence and honey. Continuous monitoring for 14 nights during each survey period Spotlight transect 300 metres across the trapping grid. Minimum 1 hour search
Brush-tailed Phascogale	Autumn/Winter and Summer	Arboreal Trapping One hectare trapping grid (100 x 100m) using ten traps (Elliot type B) set on tree rackets approximately 2-3 metres from ground level. Bait with rolled oats, peanut butter and honey. Trapping over four consecutive nights.
Spotted-tailed Quoll	Autumn/winter and Summer	Camera traps Grid of four traps per 100 hectares approximately equidistant in a grid pattern. Each trap set 3-4 metres from a small cage baited with chicken and tuna oils. Camera downloaded every 3 weeks, batteries replaced and moved to a new site for a further 3 weeks.
Long-nosed Potoroo	Winter/Spring and late summer	Camera Survey 600 x 600 metre grid with camera traps set at every 100 metre interval (n=36) Traps stations are baited with a mixture of rolled oats, peanut butter, vanilla essence and honey. Continuous monitoring for 14 nights during each survey period Spotlight transect 300 metres across the trapping grid. Minimum 1 hour search

Relative density would be recorded using the time and area based searches (capture rate per trap night or camera night or number of animals per search time and area).

7.2.4 Performance thresholds and corrective actions

There would be potential for natural variation in threatened mammal populations for a range of reasons. Further monitoring/assessment would be undertaken if a decline of population density of threatened mammals has been identified as being attributable to the construction and operation of the project. The monitoring/assessment to identify the cause of the decline and/or remedial actions would be commenced as necessary, taking into account potential causes such as dry seasons, population fluctuations and other natural variation, hence the use of unmitigated control and reference sites.

The monitoring / assessment would be dependent upon the monitoring already conducted prior to the decline being noted. Any contingency measures to be implemented would be agreed to by the relevant regulatory authorities (OEH and DSEWPaC) prior to being commenced. The key performance thresholds and corrective actions are outlined in Table 7-2.

Table 7-2 Performance thresholds for population densities

Performance threshold	Corrective actions
• Statistically significant decline in threatened mammal density at monitoring sites compared to control and reference sites over two survey periods.	• Review monitoring methods, considering further monitoring and assessment should there be a decline in population density. • Consider potential for natural variation to be responsible for decline in population numbers/density by comparison with control sites. • Review results in conjunction with the roadkill monitoring to check correlation with fence absence of breaches. • Investigate habitat adjoining the highway and consider improving habitat condition and connectivity.

7.3 Fauna connectivity structures

7.3.1 Monitoring goals

- Monitoring shows fauna crossing structures effective at facilitating the movements of threatened mammals.
- Monitoring shows fauna exclusion fencing effective at reducing road kill

7.3.2 Selection of monitoring locations

Fauna crossing structures (underpasses and overpasses) are to be monitored upon completion of construction and commence after 6 months. The selection criteria for structures to be monitored are as follows:

- The target species monitoring program will select a range of structures located within 5 kilometres from the population surveys as informed by the targeted surveys.
- All dedicated structures with the home range and dispersal range of populations are to be monitored.
- Combined underpasses that are 50 metres or more in length and located in proximity to native vegetation and target species populations will be targeted.
- Overpass structures would be targeted where these occur within range of the population surveys. Overpass structures may also be monitored as art of the koala management plan
- No combined structures that are located in cleared, disturbed or modified areas would be monitored.

Details of the targeted for threatened mammals listed previously in **Table 5-1**. The widened medians are monitored as part of the threatened glider management plan.

7.3.3 Timing and methods

The timing of surveys would coincide with the periods described in Table 7-1 and be done in conjunction with the population surveys. Lengthy periods of adaptation and habituation have been recorded for Northern Hemisphere species, however evidence suggests that use of crossing structures (specifically overpasses and underpasses) is regular shortly after construction (Bond and Jones 2008). Monitoring of selected crossings would commence six months after installation and would be undertaken biannually for the target species and continue until the success of the mitigation measures has been proven over three monitoring periods.

Monitoring of arboreal crossing structures and widening medians would be conducted under the threatened glider management plan and this would also detect the Brush-tailed Phascogale if using these structures. A separate monitoring procedure for these structures is therefore not provided.

The methodology for underpass monitoring is as follows:

- A single motion-detecting camera with infrared flash installed at the centre of the fauna crossing structures. Cameras would operate continuously for a period of eight weeks during the autumn/winter period and eight weeks during summer
- Hair-tubes placed upon fauna furniture within crossing structures and placed in habitat adjoining wildlife crossing structures. Hair-tubes would be baited with a mixture of rolled oats, peanut butter, and honey and left in place for 14 nights per monitoring period. Hair samples will be sent to an appropriately experienced specialist for identified.
- Scat searches within crossing structures including 5 metres from the entrance. Searches to be conducted when installing and checking sand plots (ie. twice per monitoring period).
-
- Sand plots have not been included as part of this monitoring methodology. The inclusion of sand plots would be reviewed following the initial results of the camera monitoring.

7.3.4 Performance thresholds and corrective actions

If during operation target threatened mammals are found to be unable or unwilling to use designated fauna crossing structures provisional options would be developed that could be implemented if research and/or monitoring identifies that additional or alternative measures are required.

Depending on the outcome of the monitoring of fauna crossing structures the following options would be considered in consultation with OEH:

- Maintenance of the existing connectivity measures.
- Update design of existing measures where feasible and reasonable.
- Consider additional offset measures to improve connectivity elsewhere.

The performance thresholds and corrective actions are detailed in Table 7-3.

Table 7-3 Performance thresholds for connectivity structures

Performance thresholds	Corrective actions
• Evidence of use of the designated connectivity structures by the targeted threatened mammals confirmed to be present in the targeted surveys adjacent to the structure. • Usage of structures by exotic predators reported over four monitoring periods.	• Review monitoring methods, considering increasing frequency, intensity and duration, to ensure individuals are identified. • Check connectivity structures for damage and repair as required. • Investigate habitat adjoining the crossing. Consider improving habitat condition and connectivity. • Review location of the connectivity structures and consider moving and/or adding structures. • Engage in consultation with regional predator control agencies.

7.4 Road mortality monitoring

7.4.1 Monitoring goals

- Zero mortality of threatened target species at mitigation sites.

7.4.2 Timing and methods

Monitoring of threatened mammal mortality along the highway would be undertaken during the connectivity structure and population monitoring periods described in Table 7-1. The survey would involve walking a transect 250 metres either side of the targeted connectivity structure on both sides of the project to collate and identify the number of road mortalities and geographic coordinates for each road kill specimen.

The GPS location of each road kill specimen would be recorded and assessed in relation to the closest fauna crossing structure to evaluate its effectiveness. The condition of the crossing structure and fauna exclusion fence in the vicinity of the road kill site would be investigated for any problems or breach and repairs, maintenance carried out as appropriate as described in Chapter 6.

7.4.3 Performance thresholds and corrective actions

Performance of the connectivity structures in preventing threatened mammal road mortalities would be measured by achievement of a zero rate of vehicle strikes. Detection of small mammal road kill can sometimes be difficult, as most individual animals if struck are thrown far from the road by the collision, or damaged too extensively to be identified. Reliance on this method alone could result in an under-estimation of the number of individuals struck by vehicles. Performance thresholds and corrective actions in Table 7-4.

Table 7-4 Performance thresholds for road mortality

Performance threshold	Corrective actions
Zero rate of target threatened mammal vehicle strikes at mitigated site for each survey.	• Repair any faulty fauna exclusion fences within three days of road kill being reported. • Re-evaluate strategies if target threatened mammals continue to avoid connectivity structures. • Check connectivity structures for damage and repair as required. • Review habitat adjoining the structure. Consider improving habitat condition and connectivity. • Review location of the connectivity structures in light of all monitoring data and consider moving and/or adding structures.

7.5 Habitat revegetation

A landscape management plan would be prepared that deals with landscaping across all areas of the project. This sections deals with habitat revegetation near crossing structures and adjacent to known populations of the targeted species where these have been disturbed during construction and are outside the exclusion fence. The number and location of sites would be determined post-construction with the aim of selecting multiple sites as a minimum around the east and western approaches to connectivity structures including land bridges and a number of plots on top of a land bridge.

7.5.1 Monitoring goal

- Evidence of successful habitat revegetation for threatened mammal species adjacent to known populations.

7.5.2 Timing and methods

Annual monitoring of revegetated areas would be undertaken using a condition assessment that evaluates the progress of revegetation by assessing cover of native vegetation and weeds and plant health. Following selection of monitoring sites, a cluster of permanent monitoring plots (20 m x 20 m) would be established in revegetation areas, with the number of plots dependent on the size of the site area. The following would be recorded in each plot:

- Native plant species richness.
- Native over storey cover.
- Native mid-storey cover.
- Native ground cover (grasses).
- Native ground cover (shrubs).
- Native ground cover (other).
- Exotic plant cover.

Monitoring of revegetation areas would commence 12 months after initial establishment and would occur annually (in spring/summer) for a period of five years or until success of the revegetation has been achieved against performance criteria. The Geographic coordinates of plot locations are to be recorded and a photograph taken of the centre of the plot from the south east corner.

7.5.3 Performance thresholds and corrective actions

Success of the revegetation would be measured by achievement of the performance thresholds detailed in Table 7-5.

Table 7-5 Performance thresholds for habitat revegetation

Performance threshold	Corrective actions
• The mean mortality of planted trees and shrubs over multiple plots at each site is greater than 30%. • Mean cover abundance in any one strata has reduced by 30%. • Mean cover of weeds is greater than 30%.	• Review maintenance schedule for revegetated areas and/or replant as required. • Undertake revegetation maintenance, i.e. replanting, replacing, fertiliser treatment, erosion control, weed control.

7.6 Nest boxes

The W2B Ecological Monitoring Program details the consistent monitoring approach for nest boxes that would be adopted across all sections of the upgrade. As the procedures for installation and monitoring of nest boxes relate to a range of fauna species the monitoring of nest boxes would be consistently applied across all project sections and would, therefore, be as detailed in the W2B Ecological Monitoring Program. Refer to the Ecological Monitoring Program for details on the nest box monitoring requirements.

7.7 Evaluation, project review and reporting

Annual reports would be prepared outlining the results of the targeted surveys and monitoring undertaken pertaining to the project. This may include a separate monitoring report per target species or a combined report for one or more species. A brief annual report would be prepared by the contractor(s) for distribution to the Roads and Maritime and other relevant government agencies (DoPI, OEH and DSEWPaC) for threatened mammals

The contractor(s) employed to undertake the threatened mammal monitoring would be responsible for the evaluation of the monitoring information collected.

A final report would be prepared at the conclusion of the monitoring period. This report would incorporate all the results of the monitoring and recommend any additional measures (if deemed necessary) to facilitate the long term survival of the target threatened mammal population in the locality.

8. Summary table and implementation schedule

Table 8.1 provides an overall example summary of the actions proposed in the above plan. It also identifies the person responsible for the actions and the estimated timing of the project.

The program schedule would be updating following a review of the approval and project timelines.

Table 8-1: Summary table and implementation schedule of management plan.

No.	Task	Responsibility	Pre-construction	Construction	Operational				
					Year 1	Year 2	Year 3	Year 4	Year 5
1. Pre-construction management									
1.1	Targeted surveys to establish baseline condition of threatened mammal habitat and populations.	Ecologists	X						
1.2	Detailed design and refinement of connectivity mitigation measures	Roads and Maritime/Contractor	X						
1.3	Identify exclusion zones and temporary fencing to protect habitats in the pre-construction phase.	Contractor	X						
2. Construction management									
2.1	Construction work method statements	Roads and Maritime/Contractor							
2.2	Construction induction and training	Roads and Maritime		X					
2.3	Installation of habitat exclusion zones	Ecologist/Contractor		X					
2.5	Pre-clearing surveys (threatened ground-dwelling mammals)	Ecologist		X					
2.6	Pre-clearing surveys (cave-roosting microbats)	Ecologist		X					
2.7	Permanent fauna exclusion fencing	Contractor		X					
2.8	Fauna connectivity structures	Contractor		X					
2.9	Habitat revegetation including at crossing structures	Contractor		X					
2.10	Water quality and hydrology	Contractor		X					
2.11	Nest boxes	Contractor		X					
3. Operational management									
3.1	Maintenance of habitat revegetation	Roads and Maritime			X	X	X	X	X
3.2	Maintenance of fauna exclusion fencing and fauna crossing structures	Roads and Maritime			X	X	X	X	X
3.3	Maintenance of nest boxes	Roads and Maritime			X	X	X	X	X
3.4	Predator control	Roads and Maritime			X	X	X	X	X
4. Monitoring program									
4.1	Threatened mammal population monitoring	Ecologist	X	X	X	X	X	X	X
4.2	Fauna crossing structures monitoring	Ecologist		X	X	X	X	X	X

No.	Task	Responsibility	Pre-construction	Construction	Operational				
					Year 1	Year 2	Year 3	Year 4	Year 5
4.3	Road mortality monitoring	Ecologist		X	X	X	X	X	X
4.4	Habitat revegetation monitoring	Ecologist		X	X	X	X	X	X
4.5	Nest box monitoring	Roads and Maritime/Ecologist			X	X	X	X	X
4.6	Evaluation and reporting	Ecologist	X	X	X	X	X	X	X

9. References

Bond, A. R., Jones, D. N. (2008) Temporal trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research*. **35**, 103–112.

Churchill, S. (2008) *Australian Bats*. 2nd edn. Allen & Unwin, Crows Nest NSW.

Department of Environment and Conservation (DEC) (2004) *Threatened Biodiversity Survey and Assessment: Guidelines for developments and activities (working draft)*. NSW Department of Environment and Conservation, Hurstville, NSW.

Department of Environment, Climate Change and Water (DECCW) (2012a) Rufous Bettong - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10033 [Accessed March 27, 2013].

Department of Environment, Climate Change and Water (DECCW) (2012b) Spotted-tailed Quoll - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10207 [Accessed March 27, 2013].

Department of Environment, Climate Change and Water (DECCW) (2012c) Long-nosed Potoroo - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10662 [Accessed March 27, 2013]

Department of Environment, Climate Change and Water (DECCW) (2012d) Eastern Bentwing-bat - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10534 [Accessed March 27, 2013].

Department of Environment, Climate Change and Water (DECCW) (2012e) Eastern Cave Bat - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10829 [Accessed March 27, 2013].

Department of Environment, Climate Change and Water (DECCW) (2012f) Little Bentwing-bat - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10533 [Accessed March 27, 2013].

Department of Environment, Climate Change and Water (DECCW) (2013) Southern Myotis - profile. [online]. Available from: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10549 [Accessed March 27, 2013].

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011) *Survey guidelines for Australia's threatened mammals*. Canberra, ACT.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012) *Potorous tridactylus tridactylus* — Long-nosed Potoroo (SE mainland). [online]. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66645 [Accessed March 27, 2013].

Department of the Environment and Heritage (2004) Australian Threatened Species - Tiger Quoll, Spotted-tailed Quoll or Spot-tailed Quoll (*Dasyurus maculatus*). [online]. Available from: http://www.environment.gov.au/biodiversity/threatened/publications/pubs/tiger-spotted-quoll.pdf [Accessed March 27, 2013].

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2010) *Survey guidelines for Australia's threatened bats*. Canberra, ACT

GeoLINK (2013) *W2G Targeted Bat Surveys – Project Summary March 2013*. A report for NSW Roads and Maritime Services.

Harris, I. M., Mills, H. R., Bencini, R. (2010) Multiple individual southern brown bandicoots (*Isoodon obesulus fusciventer*) and foxes (*Vulpes vulpes*) use underpasses installed at a new highway in Perth, Western Australia. *Wildlife Research*. **37**, 127–133

NSW National Parks and Wildlife Service (1999) Threatened species information: Brush-tailed Phascogale. [online]. Available from: http://www.environment.nsw.gov.au/resources/nature/tsprofileBrushtailedPhascogale.pdf [Accessed March 27, 2013].

Office of Environment and Heritage (OEH) (2011) *Code of Practice for Injured, Sick and Orphaned Protected Fauna*. Sydney, NSW.

Queensland Museum (2007) *The Wildlife of Greater Brisbane*. 2nd edn. Queensland Museum, Brisbane QLD.

Roads and Maritime Service (2012) *Upgrading the Pacific Highway Woolgoolga to Ballina Upgrade Working paper: Biodiversity Assessment*. November 2012.

Roads and Traffic Authority (RTA) (2011) *Biodiversity Guidelines – Protecting and managing biodiversity on RTA projects*. Roads and Traffic Authority of New South Wales.

Roads and Traffic Authority (RTA) (2009) *Use of fauna passage structures on RTA roads, Summary report*, January 2009.

Schulz, (1997). The Little Bent-wing Bat *Miniopterus australis* roosting in a tree hollow. Australian Zoologist 30(3), 329

Schulz, M. (1998). Bats and Other Fauna in Disused Fairy Martin Hirundo ariel Nests. Emu Vul. 98 184-191.

Sandpiper Ecological Surveys (2013) *Pacific Highway Upgrade – Woolgoolga to Glenugie. Aerial Crossings and Exclusion Fencing.* A report for ARUP/PB joint venture.

Taylor, B. D., Goldingay, R. L. (2004) Wildlife road-kills on three major roads in north-eastern New South Wales. *Wildlife Research*. **31**, 83–91.

10. Acronyms and abbreviations

Acronym / Abbreviation	Description
BACI	Before-After- Control-Impact
DoPI	Department of Planning and infrastructure
NSW	New South Wales
OEH	Office of Environmental and Heritage
SEWPaC	The Department of Sustainability, Environment, Water, Population and Community
Roads and Maritime	Roads and Maritime Service

Appendix A – Dr M. Schulz CV

DR. MARTIN SCHULZ
ECOLOGIST

Australian museum CONSULTING

Qualifications

Bachelor of Science (Honours) (Title: Feeding Ecology of the Hooded Plover Charadrius rubricollis), Monash University

Doctor of Philosophy: The conservation ecology of the rare golden-tipped bat *Kerivoula papuensis* and flute-nosed bat *Murina florium* (Chiroptera: Vespertilionidae)

Employment History

2011 – present	Sole contractor.
2010 – 2011	Project Manager, Ecology, Australian Museum Business Services
2008 – 2010	Senior Project Officer, Monitoring, Evaluation and Reporting Unit, Dept of Environment and Climate Change
2007 – 2008	Project Officer, Sydney Metropolitan Fauna Survey, Bioregional Data Group, Information and Assessment Section (Metropolitan), Dept of Environment and Climate Change, NSW
2006 – 2007	Acting Manager, Bioregional Data Group, Information and Assessment Section (Metropolitan), Dept of Environment and Climate Change, NSW Acting Manager, Bioregional Data Group, Information and Assessment Section (Metropolitan), Dept of Environment and Climate Change, NSW Bat Specialist – Preparing draft recovery plans on the Eastern Long-eared Bat. Consultant to the Arthur Rylah Institute, Dept of Sustainability and Environment, Victoria Fauna specialist – Conducting fauna survey of remnant bushland on the Cumberland Plain of Western Sydney. Consultant to the Dept of Environment and Conservation, NSW
2005 – 2006	Specialist fauna surveyor – Wollemi National Park, New South Wales, Contractor to the Dept of Environment and Conservation, NSW
2004- 2005	Bat Specialist – Ord River Stage 2 development area and surrounding reserves, Kununurra region, Western Australia and Northern Territory, Consultant to the Dept of Sustainability and Environment and Victoria

Positions held prior to 2004 can be supplied on request.

Expertise

20 years experience undertaking fauna surveys for threatened and native species;

Bat specialist;

Preparation of environmental reports;

Working and living in remote arid, semi arid, tropical and polar locations;

Expert threatened species advice;

Preparation of recovery plans.

Professional Affiliations

Birds Australia

Australasian Bat Society

Australasian Wader Studies Group

Australasian Seabird Group

Royal Zoological Society of New South Wales

Professional Experience

Fauna surveys and reporting for the following conservation areas: Towra Point Nature Reserve, Georges River National Park, Durridgere State Conservation Area, Goulburn River National Park.

Investigation of cave-dwelling bat usage of disused mines shafts, old railway tunnels and other structures in the Illawarra region.

Trapping and radio-tracking of the Mountain Pygmy Possum in Kosciuszko National Park, NSW.

Fauna surveys and preparation of reptile, small mammal, bat and selected bird seven-part tests and selected key threatening processes for the fauna component of an EIS in western NSW.

Fauna surveys and reporting at two major disturbance sites from past Snowy Hydro major construction works within northern Kosciuszko National Park, NSW.

Systematic fauna survey of Dalrymple-Hay Nature Reserve and reporting.

Prepared the fauna component of an REF for a proposed walking track return loop for the Madden Falls Walking Track in Dharawal National Park.

Finalising the 'National Recovery Plan for the South-eastern Long-eared Bat *Nyctophilus corbeni*', including re-assessment of threats and recovery actions.

Systematic fauna survey of Dalrymple-Hay Nature Reserve and reporting.

Baseline fauna survey and reporting of Wiarbough Nature Reserve and Mares Forest National Park in the Southern Highlands of NSW.

Identified tracks photographed on soot trays and sand pads placed in underpasses of the Pacific Highway south of Coffs Harbour, NSW

Anabat analysis of recordings made in Gardens of Stone National Park fauna survey, NSW.

Edited the Golden-tipped Bat and Flute-nosed Bat accounts for the book: "Field Companion to the Mammals of Australia".

Woodland bird surveys targeting threatened and regionally significant species in woodland remnants on private land and along road reserves in the Capertee and Wolgan Valleys, Central Highlands, NSW.

Provided expert knowledge on selected microchiropteran bat and raptor species listed as threatened in NSW to assist with the compilation of re-developed Threatened Species Priorities Action Statements for the Office of Environment and Heritage.

Provided expert knowledge for the minimum survey effort required for the Flute-nosed Bat *Murina florium* for the Queensland Department of Environment and Resource Management.

Bat survey of Kaanju Ngaachi Indigenous Protected Area for the Chuulangun Aboriginal Corporation, Cape York Peninsula.

Fauna surveys and reporting in Royal National Park, Heathcote National Parks, Garawarra State Conservation Area and Botany Bay National Park.

Established long-term monitoring projects for fauna groups that are poorly known within the state; such as medium-sized threatened macropod species (e.g. Long-nosed Potoroo and Parma Wallaby).

Marsupial Mole field surveys to determine range limits of the two species and compare current distribution with historical distributions.

Bat Expert – Captive Breeding and Future in-situ Management of the Christmas Island Pipistrelle.

Mammal Expert – Preparation and editing mammal species profiles relating to recommended survey methodology for species listed under the EPBC Act 1999.

Project Leader – Christmas Island reptile survey.

Project Officer, Sydney Metropolitan Fauna Survey, Bioregional Data Group, Information and Assessment Section (Metropolitan), Dept of Environment and Climate Change, NSW

Five-year postfire fauna study in the Woronora Plateau.

Survey design and fieldwork component of a fauna survey and vegetation mapping of western Yengo National Park

Reporting of northwestern Wollemi National Park fauna survey.

Survey design and field work components of the Dharawal Nature Reserve and Dharawal State Conservation Area fauna survey

Fieldwork and completion of Maroota State Conservation Area fauna survey.

Editing of five volume Southern Sydney fauna report.

Bat Specialist – Preparing draft recovery plans on the Eastern Long-eared Bat.

Fauna specialist – Conducting fauna survey of remnant bushland on the Cumberland Plain of Western Sydney.

Bat Specialist – Preparing background information for SPRAT database on the Bare-rumped Sheathtail-bat and Eastern Long-eared Bat.

Fauna specialist – Conducting fauna survey of Towra Point Nature Reserve, Botany Bay, Sydney. Consultant to the Dept of Environment and Conservation, NSW

Baseline surveys of birds, mammals, reptiles and frogs in a variety of reserves (e.g. Mudjarn Nature Reserve, Minjary and Woomargama National Parks, Wereboldera State Recreation Area), voluntary conservation agreement areas (Batlow and McPherson Plain VCA) and sites identified for rehabilitation within Kosciuszko National Park.

Bat Specialist – Prepared draft recovery plans on the Spectacled Flying-fox and Bare-rumped Sheathtail-bat.

Systematic and targeted vertebrate fauna surveys in the north-western section of Wollemi National Park targeting birds, mammals, reptiles and frogs.

Bat Specialist – Investigated causal factors in the decline of the Christmas Island Pipistrelle.

Bat and Bird Specialist – Prepared a literature review on the benefits and disbenefits of insectivorous birds in agricultural lands.

Bat Specialist – Fieldwork and reporting, Ord River Stage 2 development area and surrounding reserves, Kununurra region, Western Australia and Northern Territory.

Ornithologist – Wollemi and Yengo National Parks, New South Wales.

Wildlife Consultant– Preparation of the Burrowing Petrels of Macquarie Island Recovery Plan and preparation of a paper summarising Grey Petrel nesting on Macquarie Island.

Research Assistant – Walrus research program, Round Island; Marine Mammal Section, U.S. Fish & Wildlife Service, Alaska.

Systematic and targeted vertebrate fauna surveys in Yanununbeyan National Park (NP) and Crown Reserve (CR), Tallaganda NP, Courabyra Nature Reserve (NR), Downfall NR, Black Andrew NR, Wee Jasper NR, Ellerslie NR, Tumblong NR, Mullengandra NR and CR.

Wildlife Consultant (part time position) – Preparation of the Christmas Island Pipistrelle Recovery Plan.

Wildlife Consultant (part time position) – Revision of Christmas Island Shrew Recovery Plan.

Select Publications

Clarke, R.H. & Schulz, M. 2005. Land-based observations of seabirds off sub-Antarctic Macquarie Island during 2002 and 2003. *Marine Ornithology* 33, 7-17.

Cooper, S.J.B., Day, P.R., Reardon, T.B. & Schulz, M. 2001. Assessment of species boundaries in Australian Myotis (Chiroptera: Vespertilionidae) using mitochondrial DNA. *Journal of Mammalogy* 82, 328-338.

Schulz, M. 1995. Utilisation of suspended bird nests by the Golden-tipped Bat (*Kerivoula papuensis*) in Australia. *Mammalia* 59, 280-283.

Schulz, M. 1998. Bats in bird nests in Australia: a review. *Mammal Review* 27, 69-76.

Schulz, M. 1999. Leaf wrapping behaviour in the flute-nosed bat *Murina florium*. Bat Research News 40, 6-8.

Schulz, M. 2000. Roosts used by the golden-tipped bat *Kerivoula papuensis* (Chiroptera: Vespertilionidae). *Journal of Zoology* (London) 250, 467-478.

Schulz, M. 2000. Relative abundance and other aspects of the natural history of the rare Goldentipped Bat, *Kerivoula papuensis* (Chiroptera: Vespertilionidae). *Acta Chiropterologica* 1, 165-178.

Schulz, M. 2000. Diet and foraging behavior of the Golden-tipped Bat, *Kerivoula papuensis*: a spider specialist? *Journal of Mammalogy* 81, 948-957.

Schulz, M. 2004. Cooperative hunting in Subantarctic Skuas *Catharacta skua lonnbergi* at Macquarie Island. *Notornis* 51, 167.

Baker, G.B., Lumsden, L.F., Dettman, E.B., Schedvin, N., Schulz, M. & Watkins, D. 2001. The effects of forearm banding insectivorous bats (Microchiroptera) in Australia. *Wildlife Research* 28, 229-237.

Bennett, A.F., Schulz, M., Lumsden, L.F., Robertson, P. & Johnson, P.G. 1989. Pitfall trapping of small mammals in temperate forests of south-eastern Australia. *Australian Mammalogy* 12, 37-39.

de Oliveira, M.C. & Schulz, M. 1997. Echolocation and roost selection in Semon's Leaf-nosed Bat *Hipposideros semoni*. *Memoirs of the Queensland Museum* 42, 158.

Debus, S.J.S., Agnew, L.R. & Schulz, M. 2001. Surveys of the Grass Owl *Tyto capensis* in coastal New South Wales. *Australian Bird Watcher* 19, 94-102.

Eyre, T. & Schulz, M. 1996. Northern range extension of the Powerful Owl *Ninox strenua*. *Australian Bird Watcher* 16, 296-298.

Hannah, D. & Schulz, M. 1996. The bats of Jourama Falls National Park, north-eastern Queensland. *Queensland Naturalist* 34, 9-15.

Appendix B – Dr M. Schulz expert review

AM Consulting Ref: 1300892

2 October 2013

Expert Review of Threatened Mammal Management Plan

Author: Dr Martin Schulz

Relevant Experience

Martin has more than 30 years of experience in conducting fauna surveys, research and monitoring, including conducting PhD research on the Golden-tipped Bat (*Kerivoula papuensis*) at a number of sites across north-eastern NSW including Woolgoolga Flora Reserve. His experience includes research of bat usage of culverts and bridges (including abandoned Fairy Martin nests in these structures), which has been published in a number of journals including *Emu* and the *Australasian Bat Society Newsletter*. Martin knows the fauna of the area well and was team leader of a number of Comprehensive Regional Assessment (CRA) surveys carried out by the Office of Environment and Heritage (OEH) in the region and also a member of a team investigating the fauna in Wedding Bells State Forest. He also has a good knowledge of the fauna along the existing highway, having traversed the current route and roads in the Pillar Valley/Tyndale areas over a 5-year period while residing at Minnie Water. He has worked on a number of projects involving highway upgrades, including an investigation of the impacts of roads on Koalas (at Bonville, with Australian Museum Consulting) and investigations of fauna occurring around crossings of the Hume Freeway between Campbelltown and Mittagong.

Review Document

The document reviewed for this report was entitled "Woolgoolga to Ballina Pacific Highway Upgrade Threatened Mammal Management Plan" Version 0.3, dated August 2013 and received on 30 August 2013.

N.B. No information was provided in Appendix B for the reviewer to comment upon.

Summary of Key Considerations

Key Review Recommendations - General

1. Suggest including more information regarding methods of trapping during pre-clearance survey.

Individuals within the clearing footprint "may need to be trapped and relocated to similar habitat adjacent to the project". Need to outline how this will be achieved for species that are difficult to catch (i.e. Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo).

2. Recommend further consideration of seasonal factors in pre-clearance surveys.

Have not really considered the seasonal impact of clearing: Long-nosed Potoroo-breeds in late winter/early spring and again in late summer; Brush-tailed Phascogale die-off of males after May making this species more difficult to detect until early summer; Southern Myotis-mid spring to early summer and late summer to early autumn.

3. Specific information regarding features and furniture in crossing structures is limited.

There are few specific details supplied as to the furniture required in underpasses for all species considered in the Management Plan (i.e. Table A-3, Appendix A of the EIS), or who is responsible for monitoring and replacing underpass furniture.

4. Specific information regarding permanent fauna exclusion fencing where there are no designated crossing structures is limited.

Require clarity with respect to permanent fauna exclusion fencing in known habitat where there are no designated crossing structures.

5. Recommend that the management plan include provision for additional areas of fauna exclusion fencing and/or adaptation of crossing structures or potential crossing structures post-construction, if new road kill "hotspots" are detected post-construction.

The Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo are shy and difficult to survey for using conventional survey techniques, therefore it is possible that some hotspots may only be discovered post-construction (i.e. from road kill monitoring surveys or reported by members of the public). Therefore an adaptive approach is required where in such a case appropriate remedial action is undertaken, including the erection of fauna fencing and either creating additional dedicated underpasses or adapting existing structures such as culverts and bridges in the area.

6. Recommend that predators be monitored and predator control undertaken in locations where activity is detected for the duration of the monitoring program.

It is recommended that a proactive targeted predator control program is undertaken in identified hot spot areas for small to medium-sized mammals (e.g. Rufous Bettong, Brush-tailed Phascogale, Long-nosed Potoroo and cave-dwelling bats) otherwise all other management work may be for minimal return. All these species are within the size range particularly susceptible to predation by the fox and therefore a regular targeted predator control program is required in identified hot spot areas. A less favoured alternative is to undertake predator control immediately following the first monitoring period (rather than the fourth as this is too long a time frame) at hotspot areas where a high level of predator presence is identified.

7. Consider more targeted monitoring of road kill.

Concerned that monitoring for road kills is primarily reliant on the ecologist while travelling to and from monitoring sites to download cameras rather than as a dedicated program. Such a non-dedicated monitoring program over a very limited time frame is likely to be largely ineffective

thereby the location of roadkills will primarily be a function of reports from members of the public.

8. Ensure offset areas support populations of the species confirmed to occur within the project area.

Need to ensure offset areas support populations of at least the species that are confirmed to occur in the project area. This is particular the case for the Rufous Bettong, Long-nosed Potoroo and Brush-tailed Phascogale which occur very patchily across the region with relatively few hotspots areas documented.

Key Review Recommendations - Rufous Bettong

9. The Management Plan should address the potential for this species to occur outside of forest habitat.

Note that it is not restricted to forested habitat: Also occurs in the Pillar Valley (Sector 3) hotspot north to Tyndale in low grazing intensity pastureland with dense patches of grassland around wetlands and stands of trees plus treed roadside vegetation (e.g. along Wooli Road). Also occurs in sugar cane areas and weed infested habitat adjoining the Clarence River in Sector 4 along the existing highway between Tyndale and Harwood.

Therefore in all aspects of the project it needs to be taken into consideration that the Rufous Bettong occurs in weed-infested areas and patches of such areas which may otherwise be perceived as of low value may actually be important habitat which support numbers of this threatened species.

Need to include targeted surveys in non-forested habitats where this species occurs, in particular the Pillar Valley hotspot (Sector 3) where it occurs in rank grassland and also between Tyndale and Harwood (Sector 4) in rank grassland adjoining sugar plantations and the Clarence River.

10. The Plan should include initial findings of the monitoring program for this species in the Glenugie upgrade, even if it is just initial observations and thoughts by the ecologist involved.

11. If possible, consider pre-construction monitoring in hot spots, particularly in Pillar Valley (Sector 3) and Tyndale to Harwood section (Sector 4) where the species also occurs in other habitats than forested vegetation types: rank grassland in cleared/semi-cleared pastureland (in former) and rank grassland in sugar cane plantations (in latter).

Key Review Recommendations - Brush-tailed Phascogale

12. Design of nest boxes and instalment methodology should follow other projects where they have been used successfully.

13. Need to avoid undertaking pre-clearance surveys or monitoring during the male die-off period: after the mating period which occurs in May and June, plus the following months when only adult females are about until late spring/early summer. Therefore recommend trapping in summer (January) and autumn (March-April).

Key Review Recommendations - Spotted-tailed Quoll

14. Habitat exclusion zones for this species should consider low escarpments traversed by the project area which may be used as den sites. Recommend that the detailed design include additional habitat inclusion zones in such areas if data indicate the presence of quolls.

15. As this species has not been confirmed to occur in the project area even if occasional individuals are present it will be very difficult to establish meaningful monitoring sites and investigate population trends.

Key Review Recommendations - Long-nosed Potoroo

16. The only known population is in the Wardell heath (Sector 10). However, in Table 2.1 it is listed as occurring in Sectors 1-3 and 6-11. Should this be addressed in the management plan?

17. Exclusion fence all potential wet and dry heath habitats bordering the highway footprint in the Wardell heath area.

18. Overpasses for this species in Wardell Heath area to be planted out with a continuous cover of dry heath species which occur in the surrounding area.

Key Review Recommendations - Cave-dwelling Bats

19. Need to take into consideration the potential for some of these species to occur in tree hollows, Fairy Martin nests etc.

Not all of the cave-dwelling bats are confined to roosting in caves and artificial structures such as culverts & bridges but also use tree hollows (especially the Southern Myotis). This fact needs to be taken into consideration, including with respect to habitat protection zones.

Standard bat boxes are not suitable for at least some of these species. Instead need to make artificial holes or leave joins uncovered in concrete ceilings and encourage usage of culverts/bridges by the Fairy Martin as at least two of these bat species utilise these nests as roosting habitat. No details of such roosts were provided.

RMS employees or contractors not to remove disused Fairy Martin nests or mud dauber wasp nests on the ceilings of culverts or bridges post construction as these provide roosting habitat for at least three of the cave-dwelling bat species.

20. Need to take seasonal activity into consideration during pre-clearance surveys.

Need to check all culverts and bridges pre-construction for roosting bats: winter (for wintering bats of all 4 species) and mid to late spring (all 4 species, particularly for breeding Southern Myotis).

Need a third check of culverts/bridges where Southern Myotis were found roosting in first two checks for breeding activity in January-February.

21. Need to consider bats in the design of connectivity structures.

Where possible, leave natural habitat bordering watercourses/estuaries/wetlands where high bridges (>5 m such as the Clarence and Richmond River bridges) are to be used to provide movements.

Consider monitoring usage of watercourses and wetlands by bats using ultrasonic detection before construction and post construction by comparing the number of passes of each of the four species during a standardized recording period.

22. Need to outline approaches to be set in place to minimise the death of individual bats excluded from blocked up roosts as a result of the removal process if there is a lack of alternate roosts.

COMMENTS FOR EACH SPECIES OF INDIVIDUAL SECTIONS OF THE PLAN

Overall species categories (Section 1.2):

Cave-dwelling bats: This category encompassing four bat species is somewhat misleading as it indicates that all four are obligate cave-dwellers that also use artificial structures such as tunnels etc. However, this is not the case particularly for the Southern Myotis with radio-tracking studies indicating extensive use of tree hollows in live and standing dead trees in or adjacent to waterbodies, including up to 400 m from water (e.g. Lumsden and Menkhorst 1995; Caddle 1998). Further the Little Bentwing-bat also has been recorded using tree hollows in north-eastern NSW (e.g. Schulz 1997) as well as roosting in banana trees in banana plantations within the region, such as around Woolgoolga (K. Hulm, Southern Cross University). Therefore, hollow usage must be incorporated into the nest box plan, using structures that are known to be used by at least the Southern Myotis.

Habitat requirements and known or expected occurrence (Section 2.2.1):

Table 2.1 in this section does not include up-to-date information for some of the species:

Rufous Bettong:
Habitat Requirements: Note that it is not restricted to dry sclerophyll forest/woodlands in this area. Also frequently recorded in the Pillar Valley (Sector 3) north to Tyndale in low grazing intensity pastureland with dense patches of grassland around wetlands and stands of trees & roadside vegetation (e.g. along Wooli Road). Also found in rank grassland in sugar cane areas and weed infested habitat adjoining the Clarence River between Tyndale and Harwood (Sector 4) on the existing highway.

Identified Records and Project Sections: Agree that Sector 3 is a hotspot but need to extend this hotspot from Pheasants Nest north to include Pillar Valley and adjoining state forests all the way through to Tyndale. For example, this species is regularly observed around Tucabia and on roads in the Pillar Valley such as the Wooli Road. Need also to consider Sector 4 where this species is occasionally found killed on the existing highway in sugar cane plantation areas, particularly adjacent to waterways with rank grassland.

Brush-tailed Phascogale:

Identified Records and Project Sections:

- Halfway Creek to Glenugie should read Section 1-2 not 1-4.
- Need to add Section 3 as relatively common in forests adjacent to Pillar Valley north to Tyndale. For example, this species is regularly found roadkilled on the Wooli Road in the Pillar Valley area.

Spotted-tailed Quoll:

Habitat Requirements: Note that shelter sites can be in rocky areas such as low escarpments.

Spotted-tailed Quoll and Long-nosed Potoroo:

Identified Records and Project Sections:

My observations confirm these results for both species: in 5 years of constantly driving all sections of the existing highway and on roads accessing Minnie Water I never encountered either species as a roadkill or as active individuals at night. This is in contrast to the Rufous Bettong and Brush-tailed Phascogale.

Cave-dwelling Bats:

a) Little Bentwing-bat: As noted above not restricted to roosting in caves and man-made structures. Therefore, in broad habitat requirements need to include tree hollows. Also in broad habitat requirements this species occurs in a wide range of forest types and other habitats not listed such as heathland and mangroves.

This species is known to roost in culverts under the existing highway between W2B – here it roosts in cracks in the ceiling of larger culverts in a range of habitats including sugar cane plantations, such as in the Maclean area. However, it would be most unlikely to breed in these situations, but certainly some individuals use these roosts during the winter months.

Eastern Bentwing-bat: Broad habitat requirements include a wide range of forest types and other habitats not listed such as heathland and mangroves and even in towns.

Similar to the preceding species. it is known to roost in culverts under the existing highway between W2B as well as in the Pillar Valley area – here it roosts in cracks in the ceiling of larger culverts in a range of habitats including sugar cane plantations, such as in the Maclean area and in forest areas such as south of Woodburn.

Southern Myotis: As noted above this species is not restricted to roosting in caves and man-made structures. Therefore, in broad habitat requirements need to include tree hollows. Also in broad habitat requirements this species forages over water in a wide range of forest types and other habitats not listed included large artificial impoundments and estuaries, particularly where lined with mangroves. Note that it has been recorded roosting up to 400 m from the nearest water.

Further this species does not have a preference for roosting in caves that overhang pools. It extensively uses hollows of trees both standing in water and adjacent to water, including mangroves. Also this species may roosts some distance from water, for example, it was found in Queensland that some roosts in culverts on the Bruce Highway were more than 200 m from the nearest waterbody (Schulz 1998) and some 400m in tree hollows in Victoria (Caddle 1998).

This species is known to roost in culverts under the existing highway between W2B – here it roosts in bridges and cracks in the ceiling of larger culverts as well as disused Fairy Martin nests and amongst mud dauber wasp nests in a range of habitats adjacent to water including sugar cane plantations, such as in the Maclean area and adjacent to the Clarence River in the Ulmarra area, and on the road between Tyndale and the Tucabia. It is likely that this species breeds in these culverts. Additionally, it extensively uses these roosts during the winter months.

Large-eared Pied Bat: Broad habitat requirements: the roosts of this species are poorly known with few recorded and documented in NSW. The majority of documented roosts are confined to sandstone caves and abandoned mines, with several records of individuals in abandoned Fairy Martin nests in road culverts. No roosts have been found in road culverts in the area.

Further, modelling has shown this species preferentially occurs in sandstone areas close to fertile forest types which are used for foraging such as forest on alluvial flats, rainforest etc.

Key Threats (Section 2.3) and Potential Impacts Associated with the Project (Section 3.1):

Rufous Bettong:

- *Key threats:* In habitats occupied away from forests/woodlands key threats include loss of shelter sites such as removal of stands of trees and woody ground debris or slashing/overgrazing/burning of rank grassland such as adjacent to wetlands and watercourses. Other key threats in these situations are where habitat is subdivided into smaller acreages resulting in the landscape being 'cleaned up' including the removal rank grassland and woody ground debris; as well as predation by domestic dogs and road mortality.
- *Section 3.1:* Also need to consider the section from Glenugie to Pillar Valley as prime habitat (far southern portion of Sector 3).
- *Section 3.1:* Not sure I agree with the statement "severity of the impact on the regional population is low, as the species is widespread over a large portion of the bioregion". This is because Sectors 2/3 and possibly 4 appear to support larger populations than in many other parts of the region as based on qualitative observations of active individuals at night and the number of road kills.
- *Section 3.1:* In impacts on this species should not just consider the loss of 443 ha of forested habitat but also need to consider the loss of rank grassland such as adjoin wetlands and along watercourses.

Brush-tailed Phascogale:

- *Key threats:* Also likely to be impacted by hollow competition from the exotic Common Myna (*Sturnus tristis*) on the edge of cleared land or small habitat remnants.
- *Section 3.1.2:* Not sure I agree with the statement "severity of the impact on the regional population is low, as the species is widespread over a large portion of the bioregion". This is because this species is patchily distributed in the region with many areas of apparently suitable habitat having no records of this species (e.g. from CRA surveys). Areas traversed by some of the highway route are known hotspots for the species (e.g. parts of Sectors 2, 3, 6, and 7) making them of regional significance. Additionally, the precise reasons for

decline in parts of its range are unknown (DSE 2003) thereby making areas supporting relatively large populations of regional significance.

Long-nosed Potoroo:

- *Section 3.1.4:* This section only talks about the known population in the Wardell Heath (Sector 10). However, in Table 2.1 it is listed as occurring in Sectors 1-3 and 6-11. Why the anomaly and why was this not addressed?

Cave-dwelling bats:

- Note some of these species use tree hollows, in particular the Southern Myotis. Therefore, removal of hollow-bearing live and standing dead trees, including mangroves and exotic species must be considered a key threat.
- Three species (not the Large-eared Pied Bat) have been recorded roosting in culverts and bridges along the existing highway. Therefore, upgrading the current highway will result in the loss of roosting habitat and may result in the mortality of young of the Southern Myotis (if undertaken in the breeding season) or inactive wintering individuals (all three species). This must be considered a key rather than potential threat.
- Habitat fragmentation, particularly for species that generally do not feed in open situations, such as above the forest canopy or use discrete components of a habitat such as waterways must be considered a key threat. Such fragmentation may impact on roost usage located away from the highway path but situated between these roosts and prime foraging areas. Also it is possible that low wing loading species such as the Little Bentwing-bat may be unwilling to traverse across the upgraded highway footprint.
- All species forage in a wide range of habitats, therefore unsure why swamp forest in particular was highlighted for mention in Section 3.1.

Detailed Design Considerations (Section 3.2):

Cave-dwelling bats: Include:

- Creation of cave-dwelling bat roost habitat. *Note*: this does not comprise using standard bat boxes (except perhaps for the Southern Myotis) but rather making appropriate crevices and pockholes in the ceiling and establishing habitat that will be used for nesting by the Fairy Martin.
- Taking care not to destroy existing bat roost habitat in the current highway that will be upgraded by removing existing culverts and bridges supporting roosting bats, including potentially young Southern Myotis or inactive wintering individuals of three species. This impact can be mitigated by systematically surveying all culverts and bridges to be removed for the upgrade.
- Ensuring fly space under bridges crossing freshwater and tidal watercourses and waterbodies, for the Southern Myotis and Little Bentwing-bat.
- Consider bat flyspace in addition to roosting habitat when constructing habitat under- and overpasses for low-wing loading bat species (in particularly the Little Bentwing-bat and Large-eared Pied Bat) that are likely to be unwilling to traverse the open space caused by the upgraded highway footprint.

Mitigation and Monitoring Approach (Section 3.3):

Cave-dwelling bats: Include the points above in this section as bats do not really appear to have been considered in this section.

Effectiveness of Mitigation Measures (Section 3.4):

Rufous Bettong: Include the following points in Table 3.1:

- Need more information on the monitoring program in the Glenugie upgrade, even if it is just initial observations and thoughts by the ecologist involved.

- Consider additional monitoring in hot spots, particularly in the Pillar Valley and Tyndale to Harwood section (Sector 4) where the species also occurs in other habitats than forested vegetation types: rank grassland in cleared/semi-cleared pastureland (in former) and rank grassland in sugar cane plantations (in latter).

- Development of herbicide procedure: need to take into account this species in developing such plans, particularly in rank grassland areas (Sectors 3 and 4) and occurring in and adjacent to weed infested habitat along the Clarence River adjoining the existing highway in Sector 4.

Spotted-tailed Quoll:
Bushrock removal: need to make it clear that this may be an issue; especially where the highway footprint crosses rocky terrain including low escarpments which may be used as den sites.

Brush-tailed Phascogale:
Nest boxes: Additionally, note these have been successfully used for this species in the Hunter Valley, as well as other states.

Cave-dwelling bats: Include the following points in Table 3.1:
Fragmentation of habitat: Fly space for Southern Myotis and Little Bentwing-bat under bridges crossing freshwater and tidal watercourses and waterbodies. Also: in under- and overpasses consider bat habitat to provide access of low wing-loading bats across the highway at key locations, in particular the Little Bentwing-bat and Large-eared Pied Bat. Monitor usage of both access types with stationary ultrasonic detectors.

Disturbance of roost sites: Include:
a) Survey by qualified bat expert of all culverts and bridges that are proposed for removal prior on at least one occasion prior to actual removal operations. Preferably this search should be conducted during the breeding period of the Southern Myotis (in spring and again in late summer) and also during the winter period when wintering bats of three species are likely to be using some of these culverts/bridges. Such searches should include checking all cracks and crevices for roosting bats and checking abandoned Fairy Martin nests.

b) Pre-clearance of culverts:
- Not to be undertaken when Southern Myotis has young (mid spring to mid summer and again from late summer to late autumn).
- For bridge roosts – may be difficult to access all roosting habitat due to such factors as height or being above water; need to make contingencies for this.

Adaptive Management Approach (Section 3.5):

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll, Long-nosed Potoroo:
Adaptive management needs to accommodate the location of additional populations and even hotspots of one or all these species not located during the EIS or pre-construction targeted surveys. All of these species are difficult to survey and in places may occur seasonally or in low numbers and therefore may be readily overlooked. However, in the advent on additional populations (e.g. preconstruction surveys, construction clearing works or monitoring roadkills or as reported by members of the public) being found an adaptive management approach is required which may include installation of additional crossings and fauna exclusion fencing. Such contingencies need to be incorporated into the overall project plan.

Targeted Surveys (Section 4.3):

Note: Little detail on what comprises targeted surveys for these species.

Rufous Bettong: During preconstruction include:

a) Targeted surveys in non-forested habitats where this species occurs, in particular the Pillar Valley hotspot (Sector 3) where it occurs in rank grassland and also between Tyndale and Harwood (Sector 4) in rank grassland and weed infested areas adjoining sugar plantations and the Clarence River.

Long-nosed Potoroo: During preconstruction include:

a) Conduct additional targeted surveys (using remote cameras) in wet and dry heath in the Wardell area especially in the highway footprint and identified potential habitat.

b) Additionally, conduct targeted surveys (using remote cameras) in potential habitat in other sectors as per Table 2.1.

Cave-dwelling bats: During preconstruction include:

a) Targeted surveys of all culverts and bridges for roosting bats, in both the winter (for wintering bats) and spring months (for potentially breeding Southern Myotis). Then follow up with a third survey of culverts/bridges occupied by the Southern Myotis in the first two searches to investigate if breeding is occurring at this time of the year. To be undertaken by an experienced bat surveyor (see above).

b) Targeted survey of potential roost sites in tree hollows in riparian forest up to 400 m from the nearest waterbody that is to be cleared by the project. This survey is to target the Southern Myotis and Little Bentwing-bat by dusk flyout observations coupled with bat detection.

c) Identify locations with a high level of usage by the Southern Myotis, Little Bentwing-bat and Large-eared Pied Bat in order to identify areas to be incorporated for fly spaces under bridges/culverts and within designs for over- and underpasses.

d) Identify locations of high levels of activity for each species to be considered as monitoring locations and modify flyspace/under- and overpass plans accordingly.

Note: Southern Myotis can be difficult to separate ultrasonically from more common species, especially various long-eared bats (e.g. Pennay *et al.* 2004; Reinhold *et al.* 2001). Therefore, identification of monitoring and fly space locations need to include a combination of ultrasonics, trapping, spotlighting for foraging individuals and the location of roosts in culvert/bridges along the existing highway route.

Detailed design of permanent fencing and crossing structures (Section 4.4.1)

Cave-dwelling bats: Not only consider over- and underpasses but also high bridges. Such flyspace would not only allow bats to traverse from one side of the highway to the other, but also provide foraging habitat and potentially roosting habitat. Examples on the current highway include the high bridge over the Clarence River near Maclean and beneath various bridges along the Hume Freeway south of Sydney where Southern Myotis and Eastern Bentwing-bats commonly fly and forage beneath the bridge.

Identify habitat exclusion zones (Section 4.4.2)

Rufous Bettong: Habitat exclusion zones for this species will not only include forested habitat but also rank grassland which may be dominated by weed species and other habitat types where weed species may be or are prominent.

Spotted-tailed Quoll: Habitat exclusion zones for this species could potentially include any rocky escarpment area traversed by the highway footprint. Recommend that this be taken into consideration, having regard for any data that indicate the presence of quolls.

Cave-dwelling bats: Habitat exclusion zones should include:
a) Forested habitat adjacent to the highway where targeted preconstruction survey locates tree roosting or high activity levels of the Southern Myotis and Little Bentwing-bats.

Performance Indicators and Corrective Actions (Section 4.5)

Rufous Bettong: In Table 4.1 note that targeted surveys are to include non-forested habitats for example in the Pillar Valley hotspot (Sector 3) where it occurs in rank grassland and also between Tyndale and Harwood (Sector 4) in rank grassland and weed infested areas adjoining sugar plantations and the Clarence River.

Cave-dwelling bats: In Table 4.1 include:

Main Goal	Mitigation/Control Measures	Monitoring/Timing	Performance Threshold	Corrective Actions
Completed designs for connectivity mitigation measures	Conduct surveys for flyspace under bridges and culverts.	A number of times preconstruction	Designs not updated and complete before construction	Construction delayed and clearing zones have been approved.
Completed designs for connectivity mitigation measures	Conduct targeted survey for low aspect ratio bats along project corridor and ancillary sites to redefine locations and designs of connectivity structures where appropriate.	Once only. Complete detailed design and sign off prior to construction commences.	Designs not updated and complete before construction	Construction delayed and clearing zones have been approved.
Loss of cave-dwelling bat roosting habitat	Conduct surveys of all existing culverts and bridges to be destroyed during construction	Twice: winter and mid to late spring. Follow up in late summer for breeding Southern Myotis.	Designs not updated and complete before construction	Construction delayed and clearing zones have been approved.
Design of cave-dwelling bat roosting habitat	Incorporate artificial roosting habitat design into culverts and bridges which replace or are close to existing roosting habitat on the old highway or in areas of high activity for any of the four species	Complete detailed design and sign off prior to construction commences.	Designs not updated and complete before construction	Construction delayed until designs have been identified and have been approved.

Potential Impacts during Construction Phase (Section 5.1)

For Cave-dwelling bats include:

- Loss of roosting and breeding habitat (for Southern Myotis) in existing culverts and bridges along old highway that are to be destroyed.
- Habitat fragmentation, particularly for species that generally do not feed in open situations and low wing loadings, in particular the Southern Myotis, Large-eared Pied Bat and Little Bentwing-bat.

Potential Impacts during Construction Phase (Section 5.1)

Rufous Bettong:

- As part of the training incorporate that the Rufous Bettong occurs in situations other than forested habitat so that weed-infested areas which are generally considered as unsightly and "something to be got rid of" may actually be critical habitat which support numbers of this threatened species.

Installation of Habitat Exclusion Zones (Section 5.3.3)

Rufous Bettong:
Pre-clearing habitat exclusion zones need to consider known non-forested habitat, as determined by pre-construction targeted surveys.

Spotted-tailed Quoll: Habitat exclusion zones for this species may include any rocky escarpment area traversed by the highway footprint. Recommend that this be taken into consideration, having regard for any data that indicate the presence of quolls

Cave-dwelling bats:
Temporary fencing is to indicate the limits of clearing bordering forested habitat supporting tree roosts.

Pre-clearing Surveys (Threatened Mammals) (Section 5.3.4)

Rufous Bettong:

- Ecologist also needs to be present to supervise the removal of rank grassland in hot spot areas, in particular Pillar Valley, including checking for injured or displaced individuals.
- Licenced ecologist would also need to consider non-forested habitat such as rank grassland, as determined by pre-construction targeted surveys as exclusion zone areas where vegetation and habitat would be retained outside the clearing footprint.

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll, Long-nosed Potoroo:

- *Individuals within the clearing footprint would be relocated to similar habitat adjacent to the project:* need to outline how this will be achieved for species that are difficult to catch.

Long-nosed Potoroo:

- Does the ecologist also need to identify potential habitat (e.g. dense shrub layer within various typed of forested areas plus heath) in Sectors other than 10?

Pre-clearing Surveys (roosting microbats) (Section 5.3.5)

Cave-dwelling bats:

- Pre-clearing surveys need to be conducted on two occasions preconstruction: in the winter (for wintering individuals and species) and in mid to late spring (for all species, in addition to breeding Southern Myotis). A third pre-clearing survey is required in January-February of culverts found occupied by the Southern Myotis to further investigate breeding activity. The two breeding checks are required as in this part of its distribution the Southern Myotis has been found to be polyoestrous with two litter produced during the season: October-November and January-February (Dwyer 1970).
- Exclusion should involve destroying all abandoned Fairy Martin nests whether used by bats at the time of checking or not.
- Need to trial screening application as may be very difficult to attach effectively in all situations, particularly in high bridges (especially the Clarence and Richmond River bridges) at night.
- Cave-dwelling bats tend not to use bat boxes; therefore this technique probably has minimal application in this case.
- The time lag between screening or removal/blocking of used roosts and the provision of new roosts in new bridges and culverts and bridges assumes that the bats will use drilled holes in the concrete. This may not be the case and in many situations the screening may not prove effective in excluding the bats from the previously used roosts. This would be particularly the case if there is a long time lag between exclusion and provision of new roosts resulting in damage to screening by wind, heavy rain and other adverse weather. To reduce this screening would need to be constantly monitored for effectiveness in excluding the bats and the time delay would need to be minimal.

- Need to outline approaches to be set in place to minimise the death of individual bats excluded from blocked up roosts as a result of the removal process due to the lack of alternate roosts.

Clearing Procedures (Section 5.3.6)

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll, Long-nosed Potoroo:

- "If necessary fauna may need to be trapped and relocated". Need to outline how this is going to be done if the situation requires it as these species can be very difficult to capture.

Permanent Fauna Exclusion Fencing (Section 5.3.7)

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll, Long-nosed Potoroo:

- Unclear with respect to length of fencing where traversing hotspot areas i.e. may need to be considerably longer than the "at least 200 m either side of a designated structure".
- Also need to be clear that permanent fauna exclusion fencing may be required where there are no designated crossing structures in place.
- May need additional fencing where roadkills are reported.
- *For the Long-nosed Potoroo:* exclusion fence all potential wet and dry heath habitats bordering the highway footprint in the Wardell heath area.
- *For the Spotted-tailed Quoll:* exclusion fence any rocky escarpments traversed by the highway footprint (on both sides).

Fauna Connectivity Structures (Section 5.3.8)

Rufous Bettong:

- Incorporate consideration for this species in culverts and bridges to be placed in non-forested habitat supporting populations, particularly in hotspots such as the Pillar Valley, in sugarcane plantation areas between Tyndale and Harwood or where preconstruction targeted surveys have located populations occurring in rank grassland within and on either side of the highway footprint.
- There are no specific details supplied as to the furniture required in the culverts for this species (i.e. Table A-3, Appendix A of the EIS). Furniture requirements need to be established from pilot studies (e.g. current Glenugie monitoring plus recommended pilots outlined in this review) in this project and from other highway upgrades elsewhere in the region.

Brush-tailed Phascogale:

- This species also uses underpasses not just canopy bridges as per Table 5.1.
- Table 5.1: Do fauna crossings where it is stated "small to medium mammals" include this species?
- Need to ensure the majority of underpasses in Sectors 1-4 & 6-8 are also targeted towards this species.
- There are no specific details supplied as to the furniture required in the underpasses for this species (i.e. Table A-3, Appendix A of the EIS). Furniture requirements need to be established from other highway upgrades elsewhere in the state.

Spotted-tailed Quoll:

- There are no specific details supplied as to the furniture required in the under- and overpasses for this species (i.e. Table A-3, Appendix A of the EIS). Furniture requirements need to be established from other highway upgrades elsewhere in the state.

Long-nosed Potoroo:

- Unclear whether this plan feels this species needs to be considered in potential habitat in other sectors than 10. If considered then to plant out overpasses with continuous dense vegetation for this species to allow movements between the two sides of the highway footprint.

Cave-dwelling bats:

- In the design of over- and underpasses also include consideration for low aspect ratio species (i.e. Little Bentwing-bat and Large-eared Pied Bat) to use these structures so that populations in surrounding areas (where present) are not fragmented. Such habitat consideration would include the provision of free space above most of the furniture installed in the underpasses for other species. On overpasses this would include the installation of higher furniture and plantings (over time) that would encourage movements between these structures rather than traversing across open space without any shelter.

Habitat Revegetation (Section 5.3.9)

Rufous Bettong:
Need to consider as a priority revegetation which incorporates providing patches of dense ground cover for protection from predators, woody debris including logs, and grassy ground cover rather than just lines of planted shrubs and trees. Such revegetation areas need to focus in areas where important populations have been identified, in cleared landscapes where there is limited connectivity (e.g. Pillar Valley) and roadkill hotspots.

Long-nosed Potoroo:
Need to consider planting out overpasses in Sector 10 adjacent to the Wardell heath with a continuous cover of dry heath species which occur in the surrounding habitat. Continuous planting is required by this species for traversing across such otherwise open spaces, interspersed with logs and other furniture.

Hydrology and Water Quality (Section 5.3.10)

Long-nosed Potoroo:

- Ensure that the highway does result in a drawdown of the watertable in the Wardell heath area – this may have a negative impact on this species.

Nest Boxes (Section 5.3.11)

Brush-tailed Phascogale:

- Type and design of nest boxes used should also be determined from successful deployment elsewhere.

- Need to follow instalment methodology of where nest boxes have been used successfully.
- Number of nest boxes needs to be considered with respect to the fact that typically the species occurs in low densities and an individual can use more than 40 den sites in a year. These sites can include hollows, fissures in dead trees, logs and stumps and even the nests of babblers.

Cave-dwelling Bats:

- Type and design of nest boxes suitable for the Southern Myotis and Little Bentwing-bat used should also be determined from successful deployment elsewhere.
- Need to follow instalment methodology of where nest boxes have been used successfully.
- Number of nest boxes needs to be considered with respect to the fact that typically the species use multiple roosts.

Artificial Roost Structures (Section 5.3.*)

Cave-dwelling bats:
Need to have a section similar to the nest box section detailing the provision of artificial structures for cave-dwelling bats, including the provision of suitable surfaces to encourage the nesting of Fairy Martins. Such surfaces should comprise flat areas of concrete free of any flight obstructions.

Performance Thresholds and Corrective Actions (Section 5.4)

In Table 5.2:

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll, Long-nosed Potoroo:

- Incorporate comments as outlined in previous subsections of Section 5 (see above).

Cave-dwelling bats incorporate:

a) *Removal of bats from culverts and bridges:* for timing frequency this should be conducted twice: in winter for wintering bats and early summer for breeding activity in the Southern Myotis and possibly other species. Then a third follow up survey in January-February in culverts previously recorded as occupied by the Southern Myotis to look for evidence of breeding activity.

b) *Provide opportunities for daily movements of fauna across highway*: in over- and underpasses consider the provision of suitable habitat (i.e. underpasses: open airspace above the furniture virtually free of obstacles; overpasses: high furniture and plant growth to provide a stepping stone affect) to encourage movements of low aspect ratio bats that are unlikely to otherwise traverse the open space created by the highway.

c) *Provide compensatory root/shelter habitat for targeted hollow-dependent fauna:* Also consider species of bats that use tree hollows as roost, in particular the Southern Myotis and Little Bentwing-bat. As part of this consideration investigate artificial structures that can be erected in forested situations that are known to be used at least by the Southern Myotis.

Mitigation Goals (Section 6.2)

Cave-dwelling bats include:

- Maintain artificial structures in culverts and bridges for cave-dwelling bats for an eight-year period.
- Maintain culverts and bridges in open situations as suitable nesting habitat for the Fairy Martin. RMS employees or contractors not to remove disused Fairy Martin nests.

Maintenance of Habitat Revegetation (Section 6.3.1)

Rufous Bettong and Long-nosed Potoroo:

- In Rufous Bettong and Long-nosed Potoroo areas need to ensure that revegetation does not simply comprise lines of plantings with plant guards and clear ground between as this is unsuitable habitat for this species.
- *Rufous Bettong:* Need to protect rank grassland form inadvertent clearance or removal due to "unsightly" appearance by uneducated operators.
- Need to be careful with herbicide application.
- No removal of woody debris including logs. During the lifespan will need to consider further deposition of woody debris as initial woody debris breaks down.

Maintenance of Artificial Cave-dwelling Bat Structures (Section 6.3.*)

Cave-dwelling bats:
Need to have a section similar to the maintenance of nest box section (Section 6.3.3) detailing the maintenance of artificial structures for cave-dwelling bats.

Maintenance of Fauna Exclusion Fencing and Fauna Crossing Structures (Section 6.3.2)

Rufous Bettong:

- As part of regular inspections do not remove woody debris where it has been placed or could provide suitable shelter habitat for this species, particularly in identified hotspots.
- Woody debris should be placed along much of the underpass to provide shelter habitat and assist in making individuals feel more likely to traverse from side to side of the highway footprint.
- Who is going to monitor underpass furniture and replace with the appropriate structures where required?
- Pilot projects to provide additional details on maintenance of suitable habitat.

Brush-tailed Phascogale:

- Are cameras going to be set at the end of rope bridges to determine usage? If so who is responsible for their maintenance and proper functioning?
- Who is going to monitor underpass furniture positioned for this species and replace with the appropriate structures where required?

Spotted-tailed Quoll:

- Who is going to monitor under- and overpass furniture positioned for this species and replace with the appropriate structures where required?

Long-nosed Potoroo:

- As part of regular inspections do not remove woody debris where it has been placed or could provide suitable shelter habitat for this species, particularly in identified hotspots.
- Woody debris should be placed along much of the underpass to provide shelter habitat and assist in making individuals feel more likely to traverse from side to side of the highway footprint.
- Who is going to monitor underpass furniture and replace with the appropriate structures where required?

Maintenance of Nest Boxes (Section 6.3.3)

Cave-dwelling Bats: Need to include structures erected for cave-dwelling bats that also use tree holes, in particular the Southern Myotis. For these species the same factors listed in the document need to be considered.

Predator Control (Section 6.3.4)

Rufous Bettong, Brush-tailed Phascogale, Long-nosed Potoroo:
These species are in the size range of non-flying mammals weighing between 35 and 5500 g particularly susceptible to predation by the fox (Dickman 1996; NSW Scientific Committee 2008), which is likely to have been a significant factor in their decline. Therefore, due to this and the fact that feral predators (especially foxes and feral cats) readily use underpasses it recommended that a regular targeted predator control program is required in identified hot spot areas for the duration of the monitoring program.

Performance Measures and Corrective Actions (Section 6.4)

In Table 6.1:

Rufous Bettong, Brush-tailed Phascogale, Long-nosed Potoroo:
"Contribute to regional predator control where predators are found using connectivity structures": Experience from elsewhere and given the numbers of foxes and feral cats in particular in the area it is a given that these predators will be operating in under- and overpasses. Therefore as outlined above it is recommended that plans be made for regular targeted predator control in and adjacent to these connectivity structures.

Cave-dwelling bats:
a) Mitigation Goal = *Maintain fauna exclusion fencing*: also include fencing that protects riparian and adjoining habitat that links the two sides of the highway under high bridges.

b) Add: Mitigation Goal = *Monitor and maintain artificial bat roosts in culverts and bridges for a period of 8 years:* this includes repairing after flood events and unclogging artificial structures that have become infilled, including with mud dauber wasp nests.

c) *Predator control:* Consider predator control in culverts (see above comments) where breeding and significant numbers of individuals of cave-dwelling bats are recorded

Monitoring (Section 7)

Rufous Bettong: Need to incorporate findings of the Glenugie monitoring program and recommended pilot projects into this section.

Monitoring Goals (Section 7.2.1)

Rufous Bettong and Long-nosed Potoroo:

- These species are shy and frequently difficult to observe, with the latter species occurring in dense vegetation making it especially difficult to survey. Therefore population density surveys to detect density change using spotlighting will be very difficult in these species as they will be subject to significant observer bias. Remote camera trapping grids will be far more effective as is currently been done by the OEH WildCount project or for the latter species as for the statewide MER OEH camera monitoring program, which already may be sampling the Wardell heath area. However, a word of caution: cameras can record the number of crossings at a particular point but from this it is difficult to infer densities unless individuals can be identified. For example, in some sites I have had the same individual macropod photographed over 50 times during a two-week period. But this was one animal not 50 so can lead to misleading data interpretation if not careful. Also in different camera trapping periods individuals may be reluctant to remain in the area (say a fox is resident or hunters are present) resulting in few photographs compared to other periods when individuals are secure resulting in large numbers of photos of one or a few individuals due to behaviours such as grooming, resting and interacting with others.

Spotted-tailed Quoll:

- As this species has not been confirmed to occur even if occasional individuals are present it will be very difficult to investigate population trends.

Cave-dwelling bats:
In this section cave-dwelling bats were excluded.

However, they should be considered using the following goals:

- Investigate the numbers of each cave-dwelling bat species using culverts and bridges along the old highway compared to where replaced by the new highway. This should also investigate the incidence of breeding in the Southern Myotis in the old versus new highway (pre- and post-construction).
- Use bat detectors to monitor usage by cave-dwelling bats of riparian and adjoining habitat bordering watercourses, wetlands and estuaries that links the two sides of the highway under bridges (pre- and post-construction).

Monitoring Locations (Section 7.2.2)

Rufous Bettong: Monitoring locations to include non-forested habitats for example in the Pillar Valley hotspot (Sector 3) where it occurs in rank grassland and also between Tyndale and Harwood (Sector 4) in rank grassland and weed infested areas adjoining sugar plantations and the Clarence River.

Long-nosed Potoroo: Should monitoring also incorporate potential habitat in other sectors than Sector 10?

Spotted-tailed Quoll: Monitoring locations will be difficult to identify given this species was not confirmed to be present in the project footprint and reference sites could potentially be in any natural habitat within 5 km of the project.

Cave-dwelling Bats: were excluded in this section. However, the following locations should be considered based on the monitoring goals:

a) *Artificial roost usage locations:* monitoring sites should be located in close proximity to where artificial roosts were located in the old highway and where the provision of artificial roosts in the new culverts and bridges have been constructed.

b) *Riparian and adjoining habitat usage locations:* watercourses, wetlands and estuaries that links the two sides of the highway under bridges.

Timing and Methods (Section 7.2.3)

Note: Unclear in the MP where these will be undertaken, for example for Spotted-tailed Quoll and Long-nosed Potoroo where they have not been confirmed to occur and large sections of the project has been identified as of potential habitat. Also using the methodology – how far about will these surveys be undertaken in potentially suitable habitat? Also will impact/control/ reference sites around the one location be sampled simultaneously?

Rufous Bettong: What is the basis for the 600 x 600 m camera grid given that the home range for the species is in the order of 75-100 ha for males and 45-60 ha with individuals travelling in 2 to 4.5 km in a single night (Pope *et al.* 2005; Dennis and Johnson 2008)?

Brush-tailed Phascogale:

- What is the basis for the 1 ha trapping grid? N.B. the home range for the species is in the order of 20-40 ha for females and greater than 100 ha for males (Soderquist and Rhind 2008).
- Need to avoid the male die-off period: after the mating period which occurs in May and June. Also the period following when only females are about until mid to late spring. Therefore recommend trapping in summer (January) and autumn (March-April).
- Elsewhere small spring loaded mascot traps have been used more successfully than Elliott B traps – should incorporate a combination of traps to maximise capture success.
- As results based on trapping need to consider marking individuals for density estimates e.g. microchipping or tattooing ears.

Spotted-tailed Quoll:
As queried above: where will these survey sites be located and how far apart will they be given that potentially the entire route has been identified as potential habitat?

Cave-dwelling bats were excluded in this section.

However, they should be considered using the following timing and methods:
a) *Artificial roost usage locations:* manual check of artificial roosts, other cracks & crevices plus disused Fairy Martin nests and amongst mud dauber wasp nests using the same timing as the pre-construction targeted searches.

b) *Riparian and adjoining habitat usage locations:* placement of stationary Anabat or other ultrasonic detector for three consecutive nights in both pre- and post-construction phases on at least two occasions (in early summer and early autumn).

Performance Thresholds and Corrective Actions (Section 7.2.4)

Rufous Bettong and Long-nosed Potoroo:
a) Refer to comments for Section 7.2.1 above.
b) Potentially could trap these species and individually mark them to determine population trends over time. Has this been considered? It is time consuming.

Brush-tailed Phascogale:
a) Refer to comments for Section 7.2.1 and 7.2.3 above to statistically determine population trends over time (re-permanent marking).

Spotted-tailed Quoll:
a) How is it expected to determine statistically population trends over time given that the species' presence has not been confirmed in the project area?

Cave-dwelling bats: The following could be used to investigate for statistically significant changes:

a) *Artificial roost usage locations:* number of individuals present.

b) *Riparian and adjoining habitat usage locations:* number of identified passes of bats travelling along watercourses before the new bridges were constructed and following their construction.

Selection of Monitoring Locations (Section 7.3.2)

Brush-tailed Phascogale: Need to detail techniques to be used in pre-construction targeted survey to determine the location of crossing structures and monitoring locations.

Spotted-tailed Quoll: How can monitoring locations be identified given that the species' presence has not been confirmed in the project area?

Long-nosed Potoroo: Should monitoring also incorporate potential habitat in other sectors than Sector 10?

Cave-dwelling bats were excluded in this section.

However, they should be considered using the following goals:

- As mentioned above; use bat detectors to monitor usage by cave-dwelling bats of riparian and adjoining habitat bordering watercourses, wetlands and estuaries that links the two sides of the highway under high bridges (pre- and post-construction).
- Use bat detectors to investigate usage of over- and underpasses by low wing loading bat species, in particular the Little Bentwing-bat and Large-eared Pied Bat (post-construction).

Timing and Methods (Section 7.3.3)

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo:
Need to regularly check cameras installed in underpasses (and overpasses) during each 8 week period that the single camera has not been stolen.

Brush-tailed Phascogale:
Need to avoid die-off period (see comments for Section 7.2.3).

Cave-dwelling bats were excluded in this section.
However, they should be considered using the following timing and methods:

a) *Riparian and adjoining habitat usage locations:* As outlined above, by the placement of stationary Anabat or other ultrasonic detector for three consecutive nights in both pre- and post-construction phases on at least two occasions (in early summer and early autumn).

b) *Over- and underpass usage locations:* as for b) both on over- and underpasses plus in adjoining habitats.

Performance Thresholds and Corrective Actions (Section 7.3.4)

Rufous Bettong:
The Glenugie monitoring project in addition to the recommended additional pilot projects under existing roads in identified hotspots in various habitats (in particular rank grassland) should avoid the need to modify underpass structures once the project is underway.

Cave-dwelling bats were excluded in this section.
The following could be used to investigate for statistically significant changes:

c) *Over- and underpass artificial roosts:* need to redesign roosts if the artificial structures installed during the construction phase are not used.

b) *Riparian and adjoining habitat usage locations:* number of identified passes.

c) *Over- and underpass usage locations:* number of identified passes over time.

Road Mortality Monitoring (Section 7.4)

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo:
These species are shy, difficult to survey using conventional survey techniques and the last three species may occur in low densities. Therefore it is likely that some hotspots along the highway re-route may only be discovered post-construction. Consequently an adaptive approach is required where in such a case appropriate remedial action is undertaken, including the erection of fauna fencing and the creation of additional dedicated underpasses. These should then be incorporated into the overall monitoring program.

Timing and Methods (Section 7.4.2)

Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo:

- It is important that surveys of road mortality for these species be undertaken within 1 or 2 hours of dawn particularly for locating the carcasses of the smaller species which are likely to be eaten by predators including the Torresian Crow and various scavenging raptor species. Additionally, with increasing traffic after dawn carcasses may become less and less recognisable or may be bounced off the highway and thereby overlooked.
- Concerned that monitoring for road kills is primarily reliant on the ecologist while travelling to and from monitoring sites to download cameras rather than as a dedicated program. Such a non-dedicated monitoring program over a very limited time frame is likely to largely ineffective i.e. road kill studies involve dedicated searches for extended periods of time; additionally the ecologist due to time limitations may be forced to rush between locations thereby not effectively undertaking the road mortality monitoring.

Habitat Monitoring (Section 7.5)

Rufous Bettong:
Note comments for Section 6.3.1 – that this species to varying extents (depending on habitat type) requires dense vegetation for shelter and protection against introduced predators. Therefore in hotspots weed control must take this into consideration.

Summary Table and Implementation Schedule (Section 8)

Cave-dwelling bats: Add the following to Table 8.1:

Preconstruction: 1.4) Targeted surveys in winter and early summer to establish data on cave-dwelling bats utilising culverts and bridges to be removed. *Responsibility:* Experienced bat ecologist. *Timing:* Preconstruction.

Constructing Management: 2.12) Artificial bat roosts. *Responsibility:* RMS/bat ecologist. *Timing:* Construction.

Operational Management: 3.5) Maintenance of artificial roosts. *Responsibility:* RMS. *Timing:* 1-5 years.

Monitoring Program: 4.7) Artificial bat roost monitoring. *Responsibility:* Bat ecologist. *Timing:* 1-5 years.

Also: 4.1) and 4.2): Add bat ecologist for Responsibility.

Review background information to the project including the EIS and associated Biodiversity Working Paper. These reports were extensive and thorough

Agencies' comments: Issues raised have been incorporated in the above section.

Prepare a written review statement on the MP which will provide feedback on the following questions:

a) Is the design of the monitoring project appropriate?

Overall the plan is appropriate. However, note suggestions/recommendations/comments outlined above.

b) Is the frequency and timing of monitoring adequate?

Frequency: This was not clarified in sufficient detail. For example roosting habitat of cave-dwelling bats which is to be removed needs to be checked three times prior to construction: winter (for wintering individuals), mid to late spring (for breeding Southern Myotis) and occupied sites again in mid-summer for additional information on breeding habitat. For potential occurrence of species which have not been confirmed to occur there was no indication on how many times the project area will be target surveyed prior to construction.
Timing: This was not well addressed. For example, for cave-dwelling bats as mentioned above. Also taking into account breeding cycle of other species i.e. no targeted survey effort should be undertaken for the Brush-tailed Phascogale until after male die-off.

c) Is the MP clear on selection criteria for monitoring sites?

No. There was confusion for some species, particularly potentially occurring species which have not been confirmed to be present in the project area yet identified habitat included large parts of the project area. It was not clear how monitoring sites will be selected for these species, in particular the Spotted-tailed Quoll and Long-nosed Potoroo. Also unclear for other species as well.

d) Are appropriate goals being set?

Yes, but unlikely with respect to road mortality since many of these species occur at low densities and may even occur in hotspots which were not located in the target surveys. Therefore, appropriate exclusion fencing is unlikely to have been established at all of these locations. Similar, impossible to have zero kills for bat species which cannot be confined by fencing. However, road kill surveys are unlikely to detect this given the difficulty of locating killed bats, the likelihood that they have been thrown into the adjacent vegetated highway verges and that predators would quickly consume them.

With respect to clearing: unlikely that all individuals of all these species will be located and if located trapped by the ecologist.

e) Are the mitigation and management actions sufficiently targeted?

Yes, with the exception of:

a) Rufous Bettong which also occurs in non-forested habitat i.e. rank grassland in pastureland and sugar cane areas in Sectors 3 &4.

b) Cave-dwelling bats: some use tree hollows (in particular the Southern Myotis) and provision needs to be made for this. Additionally, standard bat boxes are unlikely to be used by most if not all of these species; instead artificial structures need to be provided in the bridge and culvert framework e.g. drilled holes; uncovered joins.

f) Objectives, performance measures, corrective actions and thresholds and corrective actions in accordance with SMART principles?

These are appropriate. However, an adaptive management approach is required: The Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo are shy and difficult to survey for using conventional survey techniques. Therefore it is likely that some hotspots along the highway re-route may only be discovered post-construction. Consequently an adaptive approach is required where in such a case appropriate remedial action is undertaken, including the erection of fauna fencing and the potential of using existing structures such as culverts and bridges for providing under-highway movements. Such contingencies need to be incorporated into the overall project design

g) Do the management measure objectives, performance indicators and thresholds and corrective actions link sufficiently to allow effective implementation?

To some extent. Refer to above section on comments with respect to this. Of concern, there was no mention that additional locations for these species may be found as a result of preconstruction targeted surveys or during or post-construction, particularly in road kill surveys. Therefore, it is unclear what steps will be taken if such situation arise.

Concerned about the effectiveness of the methodology planned for the staged removal of cave-dwelling bats in culverts/bridges to be removed to new habitat on the upgraded highway.

h) Has the MP provided sufficient evidence where the proposed mitigation has previously been effective?

Not really. Virtually no information provided for the effectiveness of crossings for the Rufous Bettong, Brush-tailed Phascogale, Spotted-tailed Quoll and Long-nosed Potoroo. For example, what comprises a successful crossing in terms of furniture etc; also plantings on overpasses. Additionally, did not provide information on Rufous Bettong Glenugie pilot project. No information provided on suitable design for phascogale nest boxes. No information on cave-dwelling bat shelters to be used in culverts. Also failed to mention that some of these species (in particular Southern Myotis) use tree hollows as roosts and no provision for this.

i) Does the MP describe and discuss contingencies should the proposed measures be ineffective?

Such descriptions are limited, particularly with respect to contingencies. For example, little consideration was given in the Plan in the advent of additional hotspots being located for species such as the Rufous Bettong or Long-nosed Potoroo.

j) If we can't demonstrate mitigation proposed will be effective, can we demonstrate that corrective actions will be effective?

That would require a calculated guess. Very difficult for species that have not been confirmed to be present in the project area.

k) Where there is no known research /evidence of the effectiveness of the specific measure proposed – have relevant alternative contingencies been committed to?

Not really, particularly as no information is provided on the effectiveness of specific measures proposed.

l) Have indirect impacts been addressed in the MP, as relevant?

Yes.

m) Are qualifications and experience of authors in subject field relevant?

Yes, particularly Chris Thomson.

However, there is some concern regarding the bat fauna covered in the EIS. For example, in the EIS the Eastern False Pipistrelle *Falsistrellus tasmaniensis* was confirmed to occur in the area, yet the general consensus in this region of the state is that it is restricted to high elevation forest areas such as on the New England Tableland. There were no individuals trapped in thousands of trap nights in coastal areas during the CRA surveys, other OEH surveys or during my PhD. Similarly, for mega-bats the Eastern Tube-nosed Bat *Nyctimene robinsonii* which is listed as Vulnerable under the *TSC Act* was not considered, but is known to occur in areas such as Woolgoolga Flora Reserve. The Black Flying-fox was not predicted to occur, but is widespread and increasing in the coastal lowland areas of north-eastern NSW.

References Cited

Caddle, C.R. (1998). Roost selection by the Large-footed Myotis *Myotis adversus* in southern Australia. Honour's Thesis, University of Melbourne, Melbourne.

DECC (2007). *Terrestrial vertebrate fauna of the greater southern Sydney region: Volume 2 – fauna of conservation concern including priority pest species.* NSW Department of Environment and Climate Change, Hurstville.

Dennis, A.J. and Johnson, P.M. (2008). Rufous Bettong *Aepyprymnus rufescens.* Pp. 285-286. *In*: *The mammals of Australia.* Van Dyck, S. and Strahan, R. (eds.) Reed New Holland, Sydney.

Dickman, C.R. (1996). Impacts of exotic generalist predators on the native fauna of Australia. *Wildlife Biology* **2**: 185-195.

Dwyer, P.D. (1970). Latitude and breeding season in a polyoestrous species of *Myotis. Journal of Mammalogy* **51**: 405-410.

Lumsden, L.F. and Menkhorst, P.W. (1995). Large-footed Myotis *Myotis adversus.* Pp. 182-183. *In*: *Mammals of Victoria: distribution, ecology and conservation.* Menkhorst, P.W. (ed.). Oxford University Press, Melbourne.

NSW Scientific Committee (2008). Predation by the European Red Fox – key threatening process listing. http://www.environment.nsw.gov.au/determinations EuropeanRedFoxKTPListing.htm Accessed 7 September 2013.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat calls of New South Wales: region based guide to the echolocation of microchiropteran bats.* NSW Department of Environment and Conservation, Hurstville.

Pope, L.C., Blair, D. and Johnson, C.N. (2005). Dispersal and genetic population structure in the Rufous Bettong *Aepyprymnus rufescens*. *Austral Ecology* **30**: 572-580.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales.* Queensland Department of Natural Resources and Mines, Brisbane.

Schulz, M. (1997). The Little Bent-wing Bat *Miniopterus australis* roosting in a tree hollow. *Australian Zoologist* **30**: 329.

Schulz, M. (1998). Bats and Other Fauna in Disused Fairy Martin *Hirundo ariel* nests. *Emu* **98**: 184-191.

Soderquist, T. and Rhind, S. (2008). Brush-tailed Phascogale *Phascogale tapoatafa*. Pp. 105-107. *In*: *The mammals of Australia*. Van Dyck, S. and Strahan, R. (eds.) Reed New Holland, Sydney.

Appendix C – Figures

Figure 2 -1 Threatened mammal records, predicted habitat and connectivity structures (section 1)

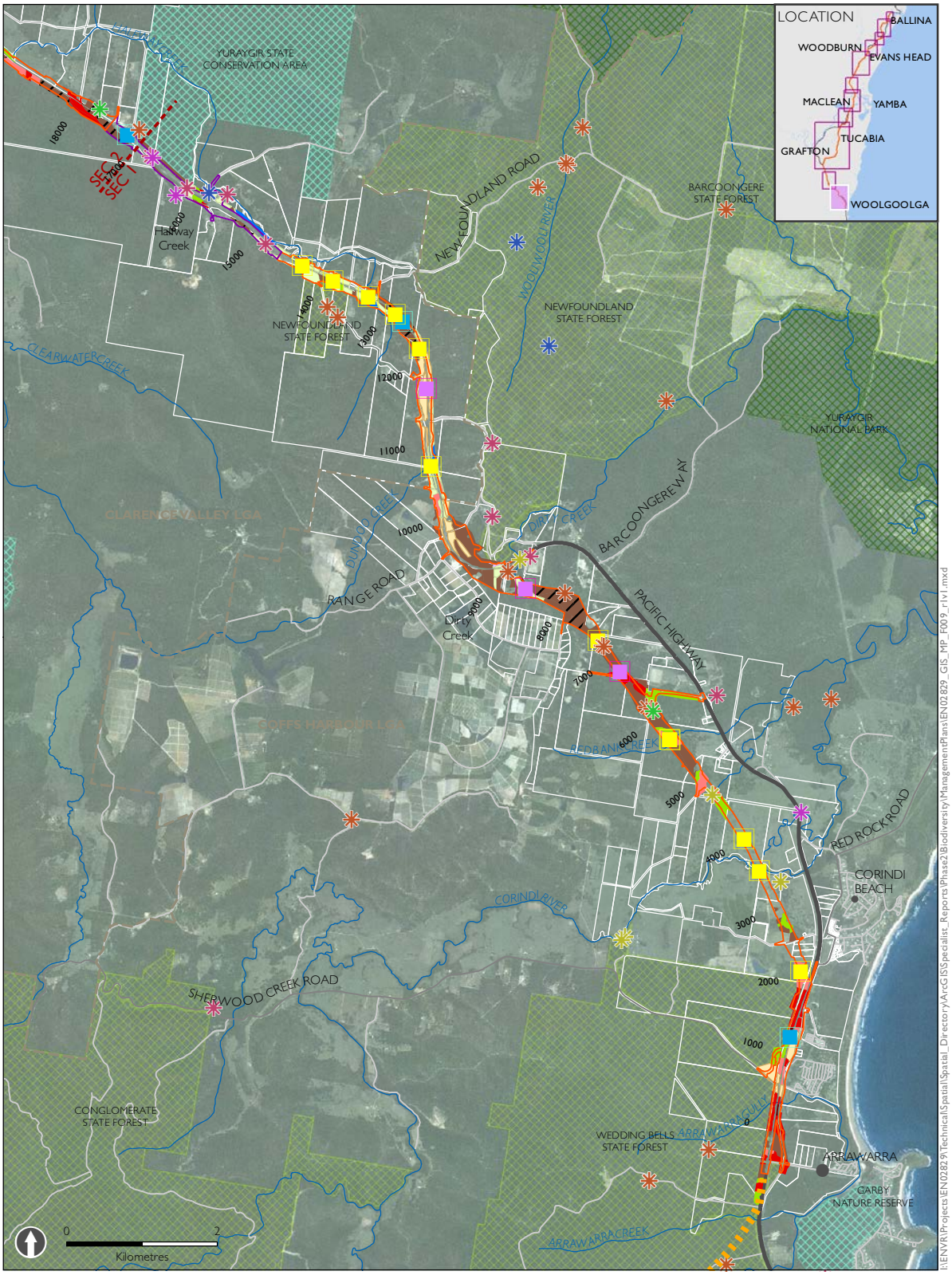
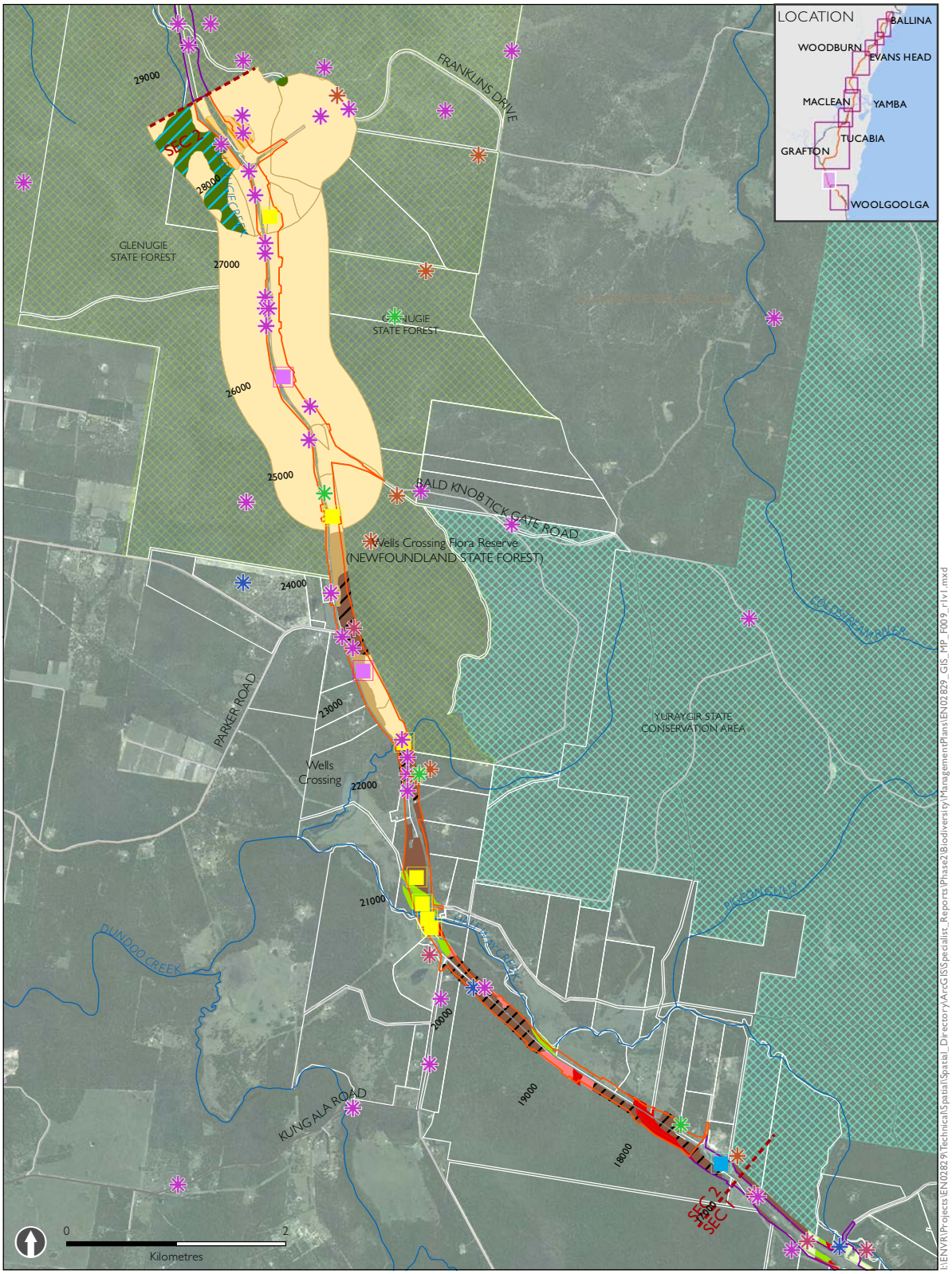


Figure 2 -2 Threatened mammal records, predicted habitat and connectivity structures (section 2)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast

Blackbutt grassy open forest of the lower Clarence Valley of the North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Narrow-leaved Red Gum woodlands of the lowlands of the North Coast

Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast

Orange Gum (Eucalyptus bancroftii) open forest of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

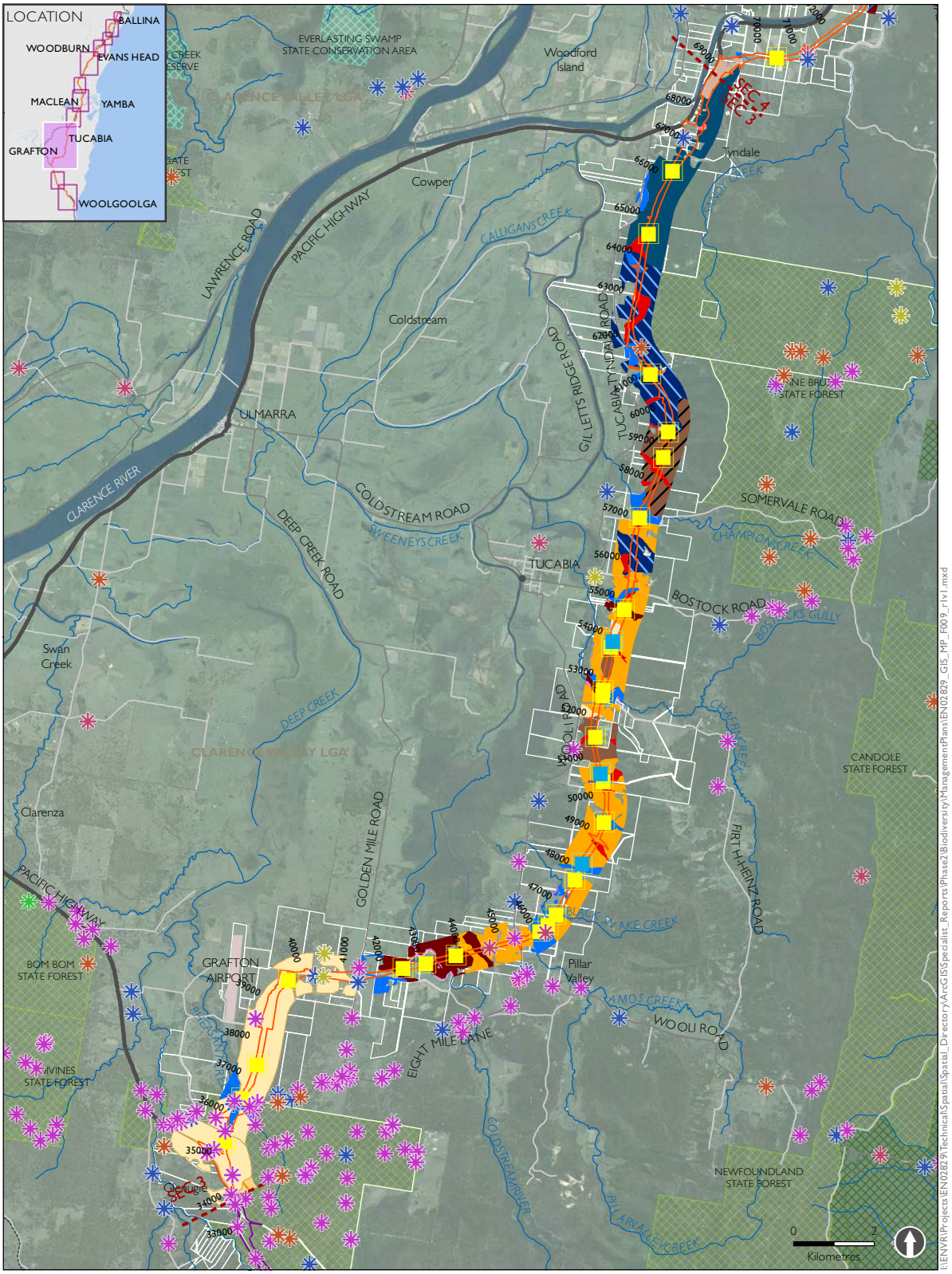
Spotted Gum - Grey Box - Grey Ironbark dry open forest of the Clarence Valley lowlands of the North Coast

Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

Swamp Box swamp forest of the coastal lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Figure 2 -3 Threatened mammal records, predicted habitat and connectivity structures (section 3)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Black Bean - Weeping Lilly Pilly riparian rainforest of the North Coast

Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast

Coastal floodplain sedgelands, rushlands, and forblands

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast

Spotted Gum - Grey Box - Grey Ironbark dry open forest of the Clarence Valley lowlands of the North Coast

Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

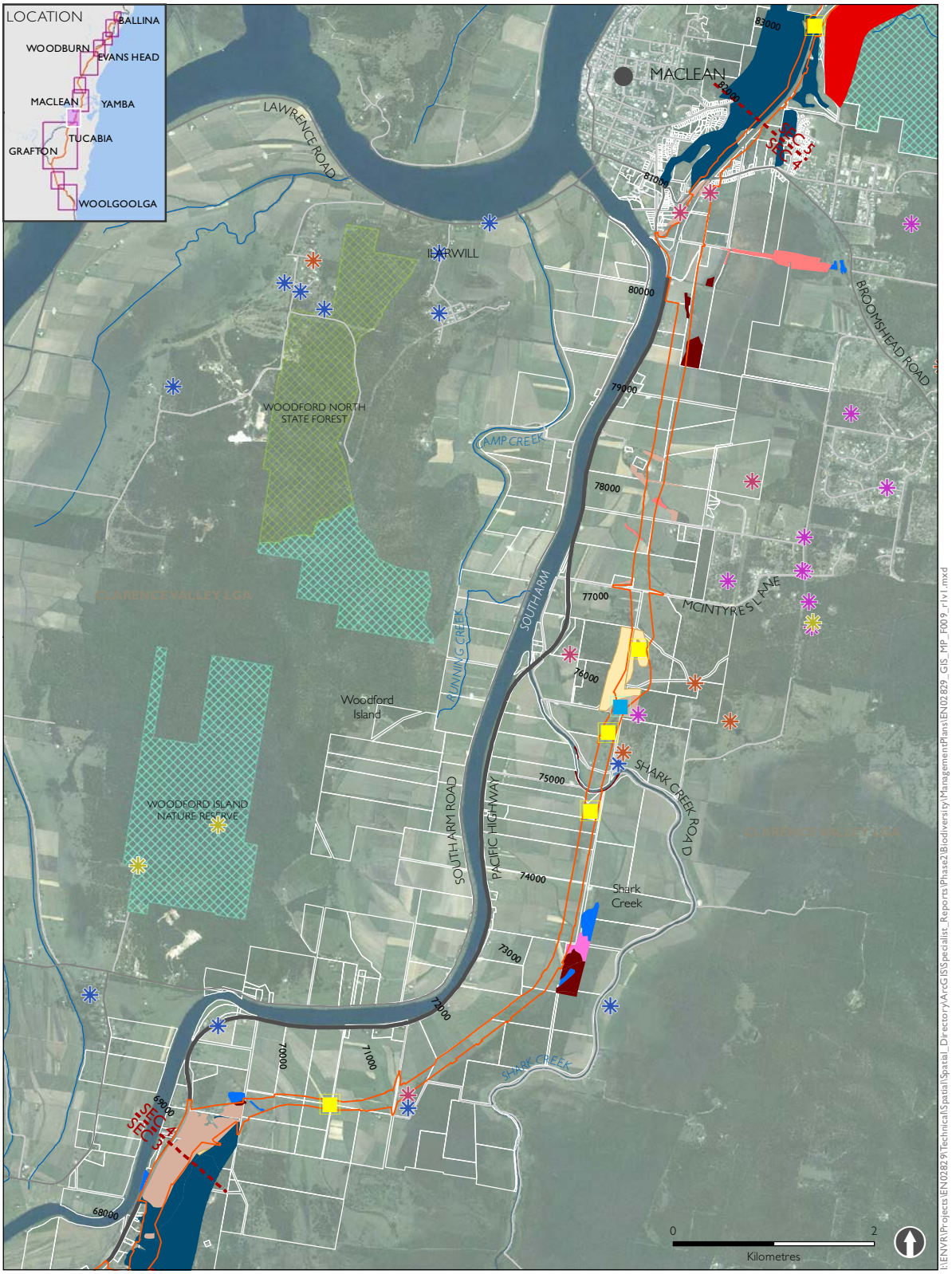
Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

Turpentine moist open forest of the coastal hills and ranges of the North Coast

Figure 2 -4 Threatened mammal records, predicted habitat and connectivity structures (section 4)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Coastal floodplain sedgelands, rushlands, and forblands

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

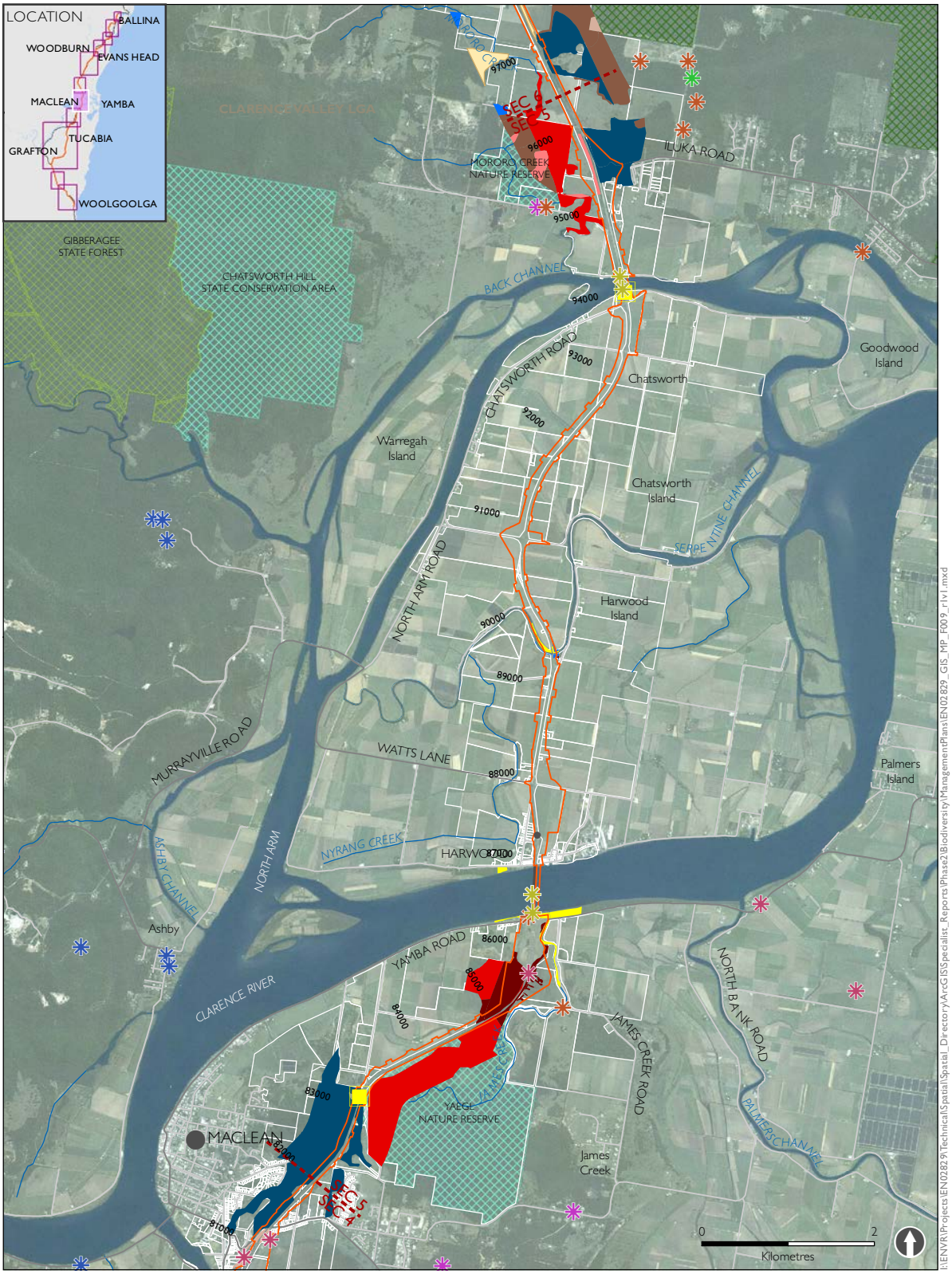
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

Figure 2 -5 Threatened mammal records, predicted habitat and connectivity structures (section 5)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Mangrove - Grey Mangrove low closed forest of the NSW Coastal Bioregions

Paperbark swamp forest of the coastal lowlands of the North Coast

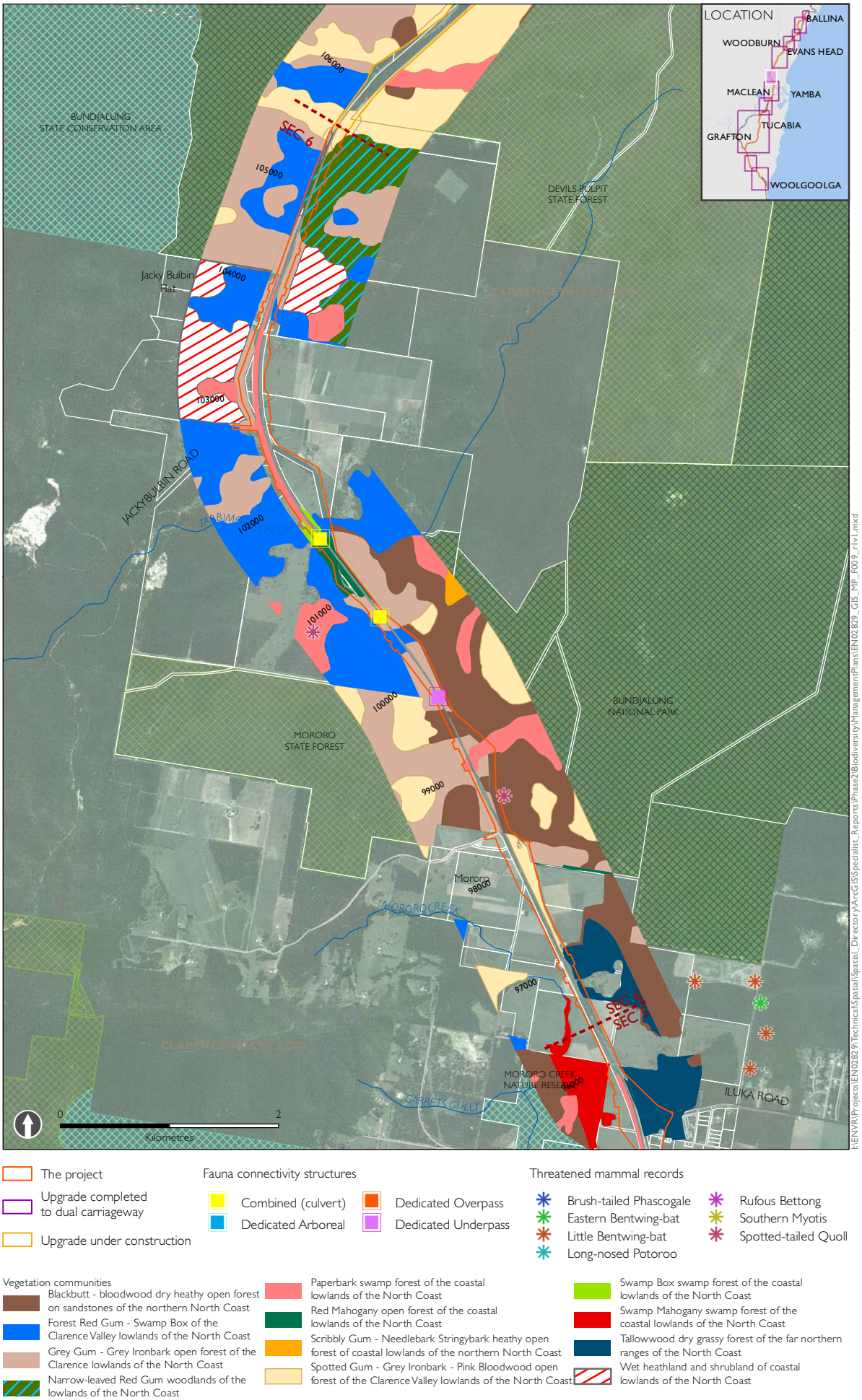
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

Figure 2 -6 Threatened mammal records, predicted habitat and connectivity structures (section 6)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Narrow-leaved Red Gum woodlands of the lowlands of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

Red Mahogany open forest of the coastal lowlands of the North Coast

Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast

Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

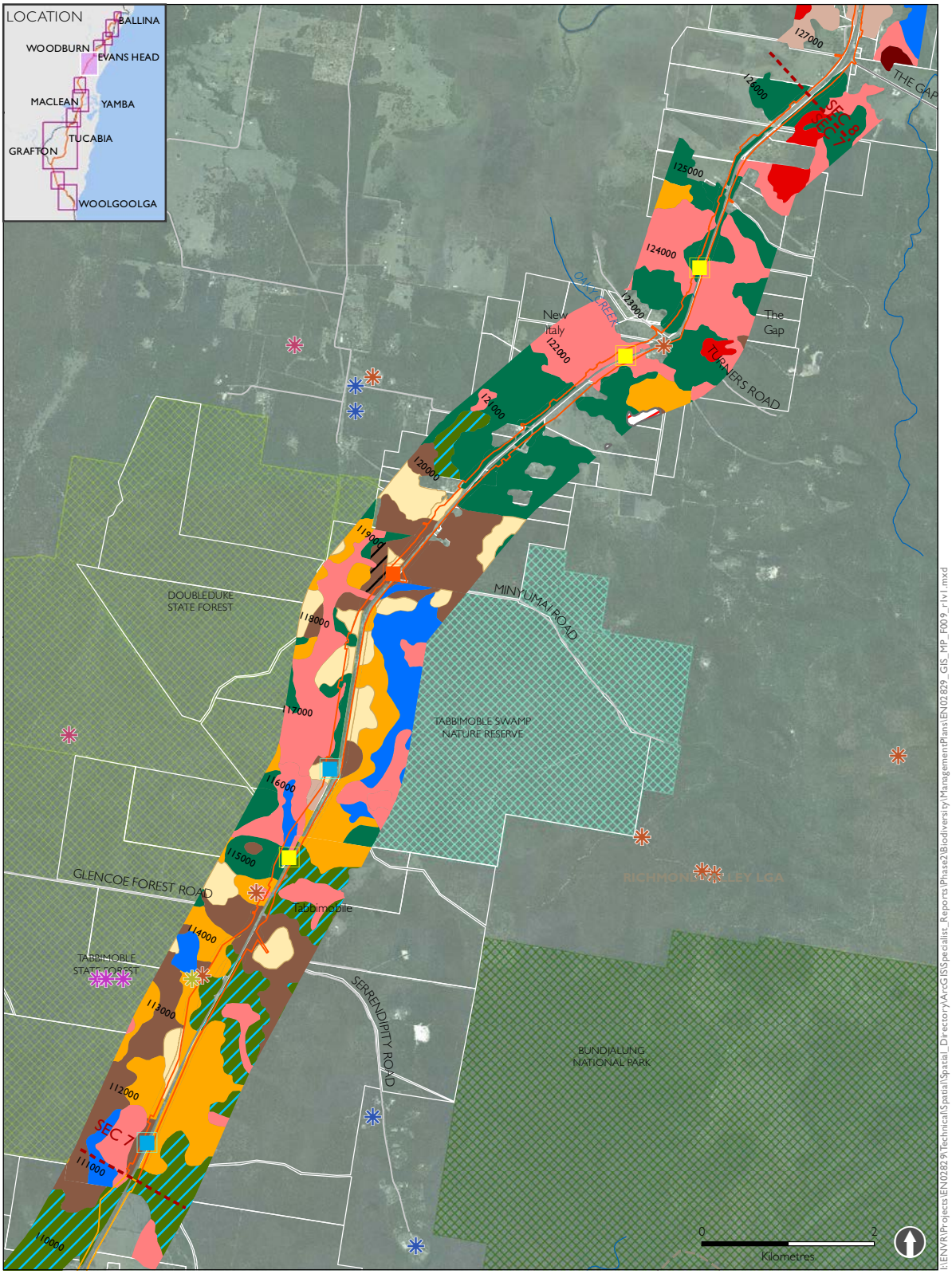
Swamp Box swamp forest of the coastal lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

Wet heathland and shrubland of coastal lowlands of the North Coast

Figure 2 -7 Threatened mammal records, predicted habitat and connectivity structures (section 7)



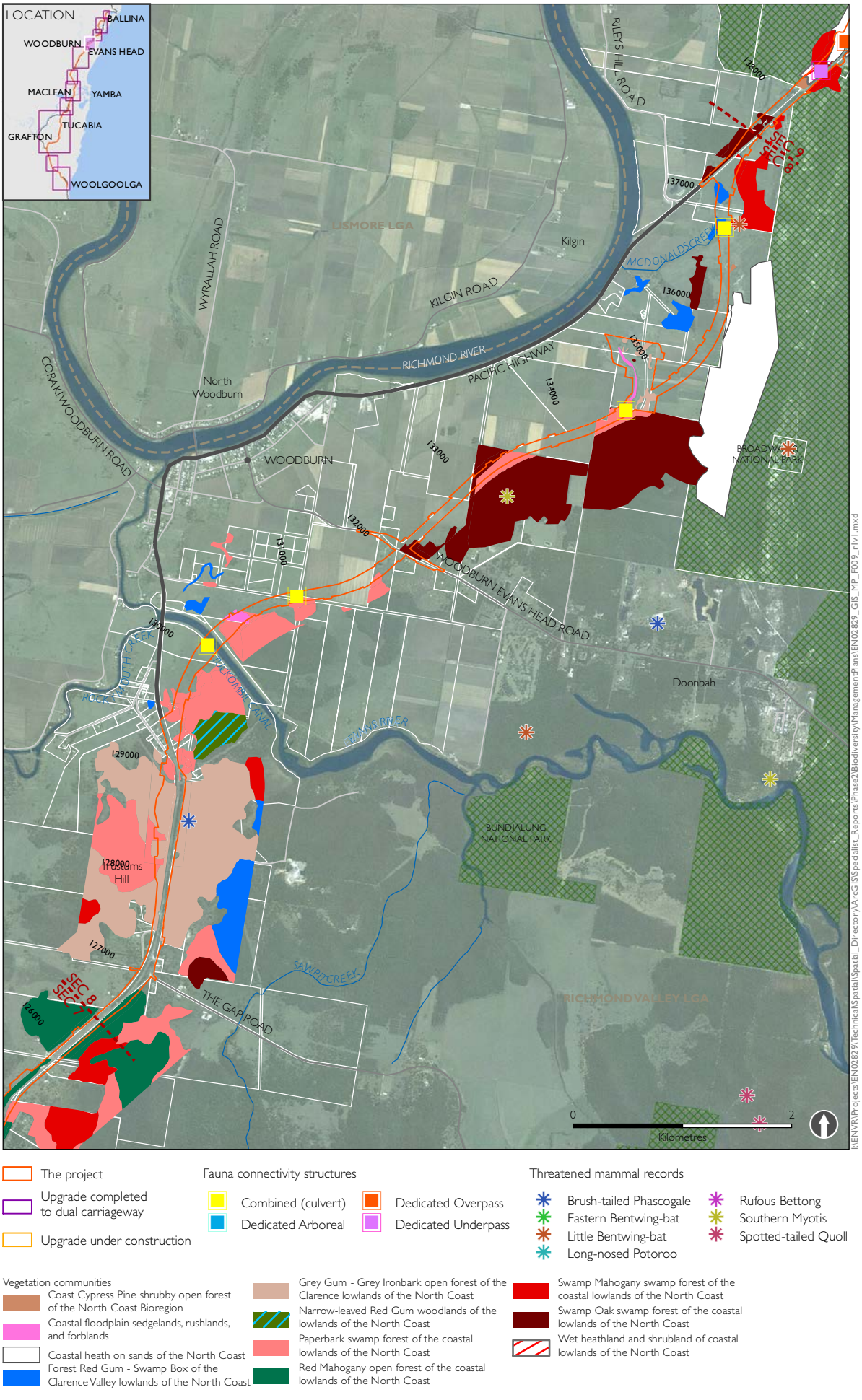
The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Combined (culvert)
Dedicated Arboreal
Dedicated Overpass
Dedicated Underpass

Threatened mammal records
Brush-tailed Phascogale
Eastern Bentwing-bat
Little Bentwing-bat
Long-nosed Potoroo
Rufous Bettong
Southern Myotis
Spotted-tailed Quoll

Vegetation communities
Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
Narrow-leaved Red Gum woodlands of the lowlands of the North Coast
Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
Paperbark swamp forest of the coastal lowlands of the North Coast
Red Mahogany open forest of the coastal lowlands of the North Coast
Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
Swamp Oak swamp forest of the coastal lowlands of the North Coast
Wet heathland and shrubland of coastal lowlands of the North Coast

Figure 2 -8 Threatened mammal records, predicted habitat and connectivity structures (section 8)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Coast Cypress Pine shrubby open forest of the North Coast Bioregion

Coastal floodplain sedgelands, rushlands, and forblands

Coastal heath on sands of the North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Narrow-leaved Red Gum woodlands of the lowlands of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

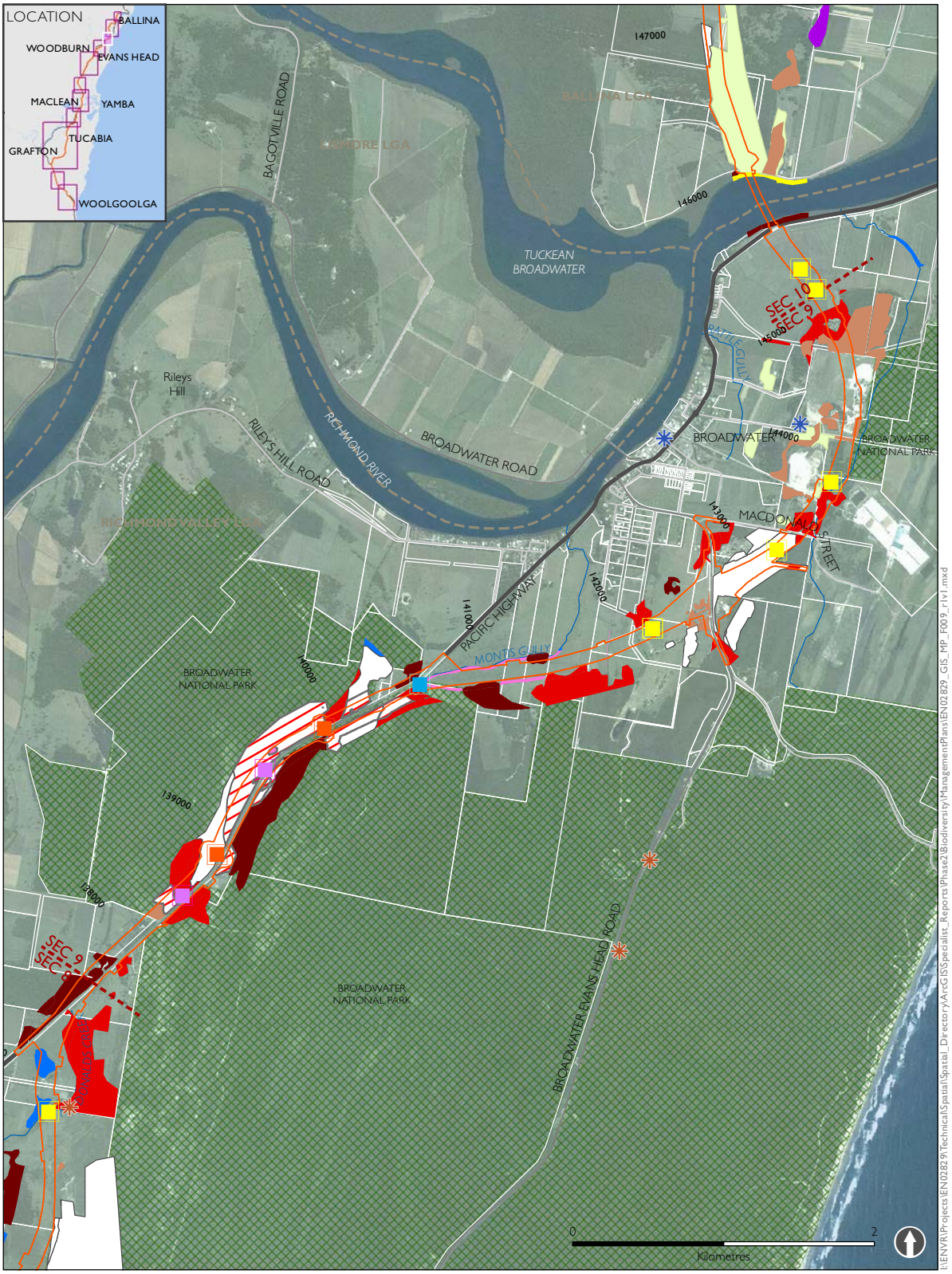
Red Mahogany open forest of the coastal lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Wet heathland and shrubland of coastal lowlands of the North Coast

Figure 2 -9 Threatened mammal records, predicted habitat and connectivity structures (section 9)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Blackbutt grassy open forest of the lower Clarence Valley of the North Coast

Coast Cypress Pine shrubby open forest of the North Coast Bioregion

Coastal floodplain sedgelands, rushlands, and forblands

Coastal heath on sands of the North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Mangrove - Grey Mangrove low closed forest of the NSW Coastal Bioregions

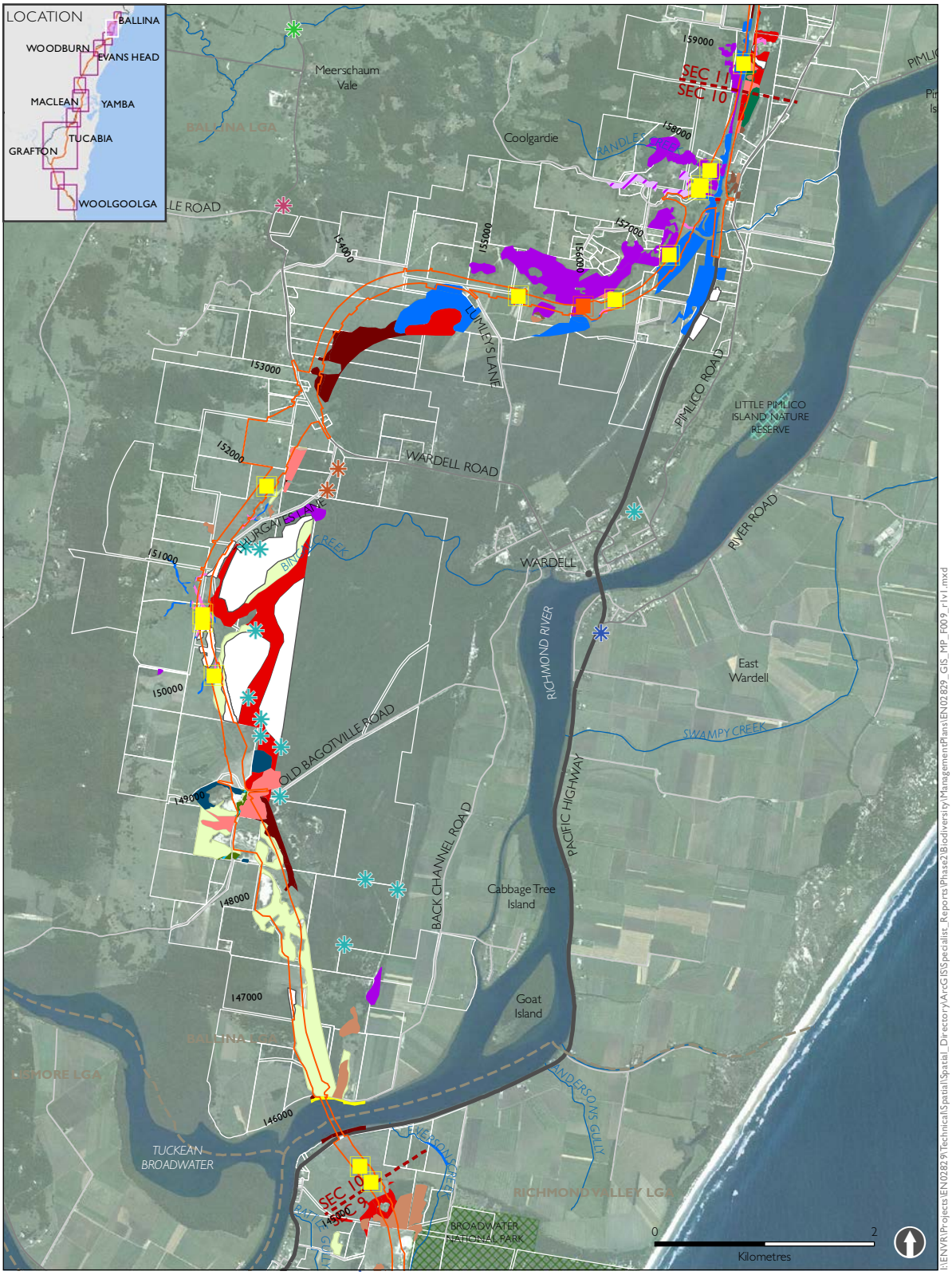
Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Wet heathland and shrubland of coastal lowlands of the North Coast

White Booyong - Fig subtropical rainforest of the North Coast

Figure 2 -10 Threatened mammal records, predicted habitat and connectivity structures (section 10)



The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Combined (culvert)

Dedicated Arboreal

Dedicated Overpass

Dedicated Underpass

Threatened mammal records

Brush-tailed Phascogale

Eastern Bentwing-bat

Little Bentwing-bat

Long-nosed Potoroo

Rufous Bettong

Southern Myotis

Spotted-tailed Quoll

Vegetation communities

Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast

Blackbutt grassy open forest of the lower Clarence Valley of the North Coast

Coast Cypress Pine shrubby open forest of the North Coast Bioregion

Coastal floodplain sedgelands, rushlands, and forblands

Coastal heath on sands of the North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Hoop Pine - Yellow Tulipwood dry rainforest of the North Coast

Mangrove - Grey Mangrove low closed forest of the NSW Coastal Bioregions

Narrow-leaved Red Gum woodlands of the lowlands of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

Red Mahogany open forest of the coastal lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

White Booyong - Fig subtropical rainforest of the North Coast

Figure 2 -11 Threatened mammal records, predicted habitat and connectivity structures (section 11)