

## 7 Assessment of key issues

*This chapter provides an assessment of the key environmental issues associated with construction and operation of the project, as identified in the Director-General's requirements for the environmental assessment (DGRs), which are attached in Appendix A. The proposed impact mitigation and management measures for the project are also identified. The key environmental issues associated with the project are:*

- *Impacts on ecology.*
- *Impacts on channel structure- receiving environments.*
- *Operational traffic and transport implications.*
- *Operational noise impacts.*
- *Aboriginal cultural heritage.*
- *General construction impacts.*

### 7.1 Impacts on ecology

Director General's requirements	Where addressed
<b>Impacts on Ecology</b> – the Environmental Assessment must include an assessment of the potential ecological impacts of the project, with specific reference to ... <ul style="list-style-type: none"><li>– The need for vegetation clearing and</li><li>– The associated habitat and connectivity implications for the range of species present.</li></ul>	Section 7.1.2
The Environmental Assessment must make specific reference to impacts on threatened species, populations and communities, particularly the Square-fruited Ironbark ( <i>Eucalyptus tetrapleura</i> ) and Weeping paperbark ( <i>Melaleuca irbyana</i> ).	Section 7.1.2
The Environmental Assessment must also make specific reference to impacts on the ecology of the Glenugie State Forest.	Section 7.1.2
Assessment of ecological impacts must be undertaken in accordance with the guidance provided in draft <i>Guidelines for Threatened Species Assessment under Part 3A</i> (DECC, 2006) and <i>Significant Impact Guidelines</i> (DEH, 2006), as relevant.	Section 7.1.2

#### 7.1.1 Existing environment

##### **Landscape context**

The study area lies within the NSW North Coast Bioregion. About 202 threatened flora species found in the North Coast Bioregion are listed in the schedules of the NSW *Threatened Species Conservation Act 1995* (TSC Act). Of these, 108 are endangered, 89 are vulnerable and five are considered extinct in the bioregion (NPWS 2002a). About 157 fauna species recorded in the North Coast Bioregion are listed in the schedules of the TSC Act (NPWS 2002b). Of these, 36 are listed as endangered and 121 are listed as vulnerable. A major factor which contributes to this high species diversity is

the location within the MacPherson-Macleay Overlap Zone. This zone is defined as the area of eastern Australia where the Tropical and Temperate Zones overlap (Burbridge 1960). Of all of the NSW Bioregions, the NSW North Coast Bioregion has the second highest proportion of lands under conservation reserves, with a total of 18.65 per cent of the bioregion conserved. There are nine conservation reserves within 20 km of the project.

A number of State Forests are located within the landscape including Glenugie, Bom Bom, Newfoundland, Candole, Divines and Pine Brush. The project is located entirely within Glenugie State Forest, which supports habitat for a diversity of native flora and fauna species, including threatened and rare species. In particular, Glenugie State Forest supports populations of the threatened species Square-fruited Ironbark (*Eucalyptus tetrapleura*), Weeping Paperbark (*Melaleuca irbyana*), Yellow-bellied Glider (*Petaurus australis*), Rufous bettong (*Aepyprymnus rufescens*), Brush-tailed Phascogale (*Phascogale tapotafa*), threatened bats, large-forest owls and other threatened bird species.

### Terrestrial Flora

There are two vegetation types associated with the project corridor (refer to **Table 7-1-1** and **Figure 7-1-1**):

- Dry sclerophyll open forests.
- Moist sclerophyll forests.

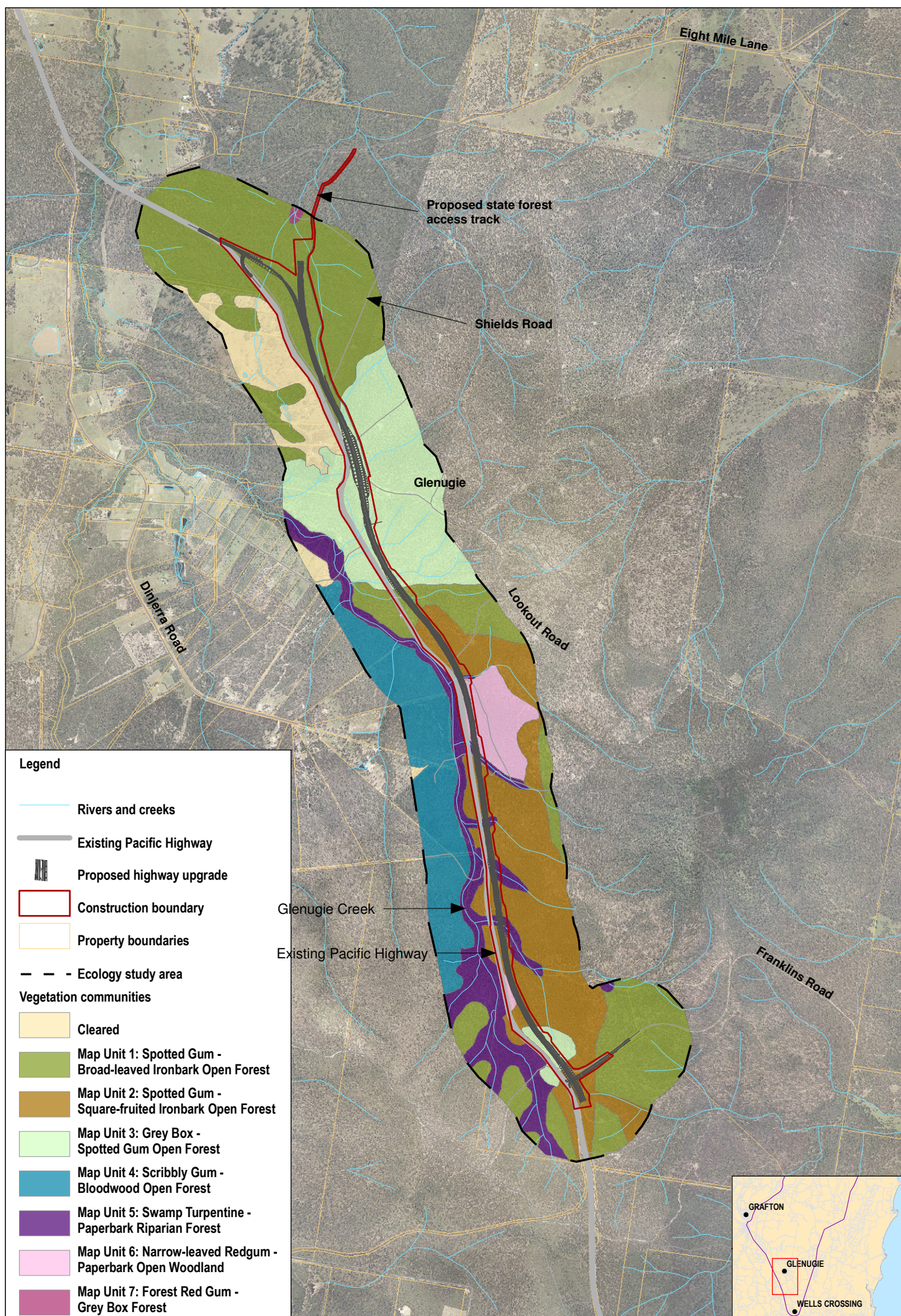
The diversity and abundance of exotic species within the study area is generally low. Of the 242 flora species recorded, 32 (13 per cent) are introduced species, with the remaining 87 per cent being native species indigenous to the local area. Exotic species are found mainly along roadsides, trails and areas of disturbed vegetation. Low abundances of the noxious weeds Lantana (*Lantana camara*) and Camphor Laurel (*Cinnamomum camphora*) are present within some areas of intact bushland, particularly in areas of high soil fertility such as along drainage lines. Introduced species are generally absent from areas of intact dry sclerophyll forest, apart from isolated occurrences of minor pasture weeds such as *Richardia* spp. and Cudweed (*Gamochaeta spicata*).

■ **Table 7-1-1 Vegetation types in the study area**

Vegetation community		Description
<b>Dry sclerophyll open forests</b>		
Map Unit 1	<b>Spotted Gum – Ironbark Forest</b>	<p>This community occupies drier elevated areas generally with clay soils and is dominated almost exclusively by Large-leaved Spotted Gum (<i>Corymbia henryi</i>) and Broad-leaved Ironbark (<i>Eucalyptus fibrosa</i>), although other species occasionally occur including Small-fruited Grey Gum (<i>E. propinqua</i>) and Grey Box (<i>E. moluccana</i>). This community occurs throughout the study area and is widespread throughout Glenugie State Forest. The understorey includes open grassy areas with patches of shrub thickets dominated by Ball-honey Myrtle (<i>Melaleuca nodosa</i>).</p> <p>The threatened flora species Square-fruited Ironbark (<i>E. tetrapleura</i>) may occur as isolated occurrences in this community, particularly where it adjoins the Spotted gum – Square-Fruited Ironbark Forest community. The threatened species Weeping Paperbark (<i>Melaleuca irbyana</i>) also occurs in this community, mainly in more protected areas surrounding drainage lines and depressions.</p>
Map Unit 2	<b>Spotted Gum – Square-fruited Ironbark Forest</b>	<p>This association typically occurs on sandy clay soils with a slightly higher soil-moisture content or water table in the central and southern areas of the study area. This forest type is dominated almost exclusively by Large-leaved Spotted Gum and Square-fruited Ironbark.</p> <p>The understorey is often dominated by a highly to moderately dense sub-canopy. The groundcover includes similar species as present in the Spotted Gum – Ironbark Forest community. The threatened flora species Square-Fruited Ironbark (<i>E. tetrapleura</i>) is a dominant component of this community occurring in relatively high abundance. The threatened species Weeping Paperbark (<i>Melaleuca irbyana</i>) also occurs on the northern edge of this community.</p>
Map Unit 3	<b>Grey Box – Spotted Gum Forest</b>	<p>This community occurs within lower elevated areas of Glenugie State Forest on clay soils mainly towards the northern end of the study area (with a small occurrence at the southern end). Dominant species comprise Grey Box and Large-leaved Spotted Gum with several other species occurring as subdominants, particularly along drainage lines including Small-fruited Grey Gum, Northern Grey Ironbark (<i>E. siderophloia</i>) and Forest Red Gum (<i>E. tereticornis</i>).</p> <p>The understorey comprises a mix of shrub patches and grassy areas supporting a diversity of grass and forb species. This community contains a moderate diversity of groundcover species similar to those in the Spotted Gum – Ironbark Forest and Spotted Gum – Square-fruited Ironbark Forest. The threatened species Weeping Paperbark (<i>Melaleuca irbyana</i>) occurs on the southern edge of the main patch of this community.</p>

Vegetation community		Description
Map Unit 4	Scribbly Gum – Bloodwood Forest	This community occurs outside the project corridor west of Glenugie Creek on the other side of the existing highway and is confined to areas with sandy soils. Dominant species comprise Scribbly Gum ( <i>E. signata</i> ), Pink Bloodwood ( <i>Corymbia intermedia</i> ) and Red Bloodwood ( <i>C. gummifera</i> ). This forest contains a high-moderate diversity of shrub and groundcover species.
<b>Moist sclerophyll forests</b>		
Map Unit 5	Swamp turpentine - paperbark riparian forest	This community occupies areas where flooding is intermittent with sandy alluvial soils including some of the tributaries of Glenugie Creek which extend into the project corridor and areas on the western side of the existing highway surrounding Glenugie Creek. The community contains a mixed canopy generally dominated by Swamp Turpentine ( <i>Lophostemon suaveolens</i> ), Red Mahogany ( <i>E. resinifera</i> ) and Narrow-leaved Red Gum ( <i>E. seeana</i> ). Several other canopy species are present in areas of this community including those from surrounding dry sclerophyll forest communities. An open shrub cover or sub-canopy is present in some areas. Other understorey species includes a mix of shrubs grasses and forbs similar to other communities in the study area. Several mesic flora species are also present within and surrounding drainage lines. A low abundance of <i>Lantana camara</i> and several other minor weed species are present in this community.
Map Unit 6	Narrow-leaved red gum - paperbark woodland	This association is generally positioned on the lower elevated areas of Glenugie State Forest on sandy clay soils in the central area of the study area. This community supports an open to very open canopy with a dense sub-canopy of shrub species. Dominant canopy species comprise Narrow-leaved Red Gum and Square-fruited Ironbark with Large-leaved Spotted Gum and Pink Bloodwood also occurring in low abundance. A dense sub-canopy is also present. The groundcover is relatively low in diversity with a sparse cover due to the dense sub-canopy limiting light penetration. The threatened flora species Square-fruited Ironbark ( <i>E. tetrapleura</i> ) is a dominant component of this community occurring in relatively high abundance.
Map Unit 7	Forest red gum - grey box forest	This community occurs on alluvial soils associated with Pheasants Creek outside the northern end of the project corridor. Dominant species include Forest Red Gum, Grey Box, Northern Grey Ironbark, Broad-leaved Apple ( <i>Angophora subvelutina</i> ) and Pink Bloodwood. This association exhibits disturbance from logging activities and inappropriate fire regimes as well as agricultural activities, resulting in a simplified understorey containing several weed species.





Data Sources  
 Topodata: Streetworks, LPI 2008  
 Aerial: 2007

**Figure 7-1-1: Vegetation communities in the study area**



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Threatened flora in the study area are listed in **Table 7-1-2** and recorded locations are shown in **Figure 7-1-2**. There are records for 15 threatened flora species identified within a 10 km radius of the road corridor and an additional 23 threatened flora species identified as potentially occurring from database searches and literature reviews. Although only Square-fruited ironbark (*Eucalyptus tetrapleura*) and Weeping paperbark (*Melaleuca irbyana*) were identified in the field surveys, there is the potential for additional species such as Leafless Tongue Orchid (*Cryptostylis hunteriana*) and *Maundia triglochoides* to occur in the study area. Flora surveys have primarily been undertaken in autumn and winter within the study area and therefore there may be flora species which were not easily detectable during the survey period. Additional surveys will be undertaken within the proposed road corridor to target cryptic rare and threatened flora species such as orchids and other cryptic flora that primarily flower during spring and summer.

■ **Table 7-1-2 Threatened flora in the study area**

Species*	Conservation status**			Distribution and abundance
	EPBC Act	TSC Act	RoTAP	
<b>Square-fruited ironbark</b> ( <i>Eucalyptus tetrapleura</i> )	V	V	2Vca	A large population of <i>Eucalyptus tetrapleura</i> is present within and surrounding the project corridor. The local population occurs as a larger contiguous population with several smaller isolated sub-populations within an approximate six kilometre radius of the project corridor. The local population is estimated to comprise 147,000 individuals. Of this total, an estimated 6,156 trees (4.2 per cent) would be removed by the project. The current known extant of <i>E. tetrapleura</i> occupies a 5,000 km <sup>2</sup> area entirely centred on the north coast of NSW. This population is considered to comprise at least 50 different sub-areas and between 170,000 and 250,000 trees. In this context, the project would remove between 2.5 per cent and 3.6 per cent of the total population.
<b>Weeping paperbark</b> ( <i>Melaleuca irbyana</i> )	-	E	-	The project would impact a small population of the threatened plant species <i>Melaleuca irbyana</i> (between 5-10 trees).
<b>Leafless Tongue Orchid</b> ( <i>Cryptostylis hunteriana</i> )	V	V	3VC-	The study area supports potential habitat and is within the natural distributional range for this species. This species does not have well defined habitat preferences and is known from forests, swamp-heath and woodland. Surveys were not undertaken within the flowering period for <i>Cryptostylis hunteriana</i> . The habitat attributes in the study area are not optimal and there is only one record of this species within the region about 13 km southeast of the study area. Considering the above it is unlikely that this species occurs in the study area, however it is recommended that surveys be undertaken for this species during spring/summer.

Species*	Conservation status**			Distribution and abundance
	EPBC Act	TSC Act	RoTAP	
<b>Small Pale Grass-lily</b> ( <i>Caesia parviflora</i> var. <i>minor</i> )	-	E	-	Found in damp places in open forest on sandstone. There is potential habitat for this species in the study area although not optimal. It is recommended that surveys be undertaken for this species during spring/summer when this species is flowering.
<b>Swamp Foxglove</b> ( <i>Centranthera cochinchinensis</i> )	-	E	-	Uncommon. Occurs in swampy areas and other moist sites. Known to occur east of the study area around Wooli.  This species is potentially present within swampy areas along watercourses in the study area, although habitat is limited. This species flowers during summer/autumn and would have potentially been flowering during the survey period during late autumn. It is considered unlikely that this species is present in the study area, however it is recommended that this species be included in any targeted threatened flora surveys in swampy habitats.
<b>Maundia triglochinoides</b>	-	V	-	Grows in swamps, creeks or shallow freshwater (30-60 cm deep) on heavy, low nutrient clays. Flowering occurs during warmer months and is associated with wetland species such as <i>Triglochin procerum</i> .  There are suitable areas of habitat along creek lines with water holes supporting <i>Triglochin procerum</i> in the study area. Despite searches being undertaken for <i>Maundia triglochinoides</i> no individuals were identified, although searches were not undertaken during the optimal flowering period. It is recommended that surveys be undertaken for this species during spring/summer.
<b>Cryptic Forest Twiner</b> ( <i>Tylophora woollsi</i> )	E	E	2E	This species grows in moist eucalypt forest, moist sites in dry eucalypt forest and rainforest margins. Flowering occurs in summer and autumn, usually between January and March. Plants appear to persist as a network of stems under leaf litter when aerial stems are absent.  This species is potentially present surrounding water courses, although It is considered unlikely that this species is present in the study area. However it is recommended that this species be included in any targeted threatened flora surveys along watercourses.

\* Either identified during surveys or considered to potentially occur.

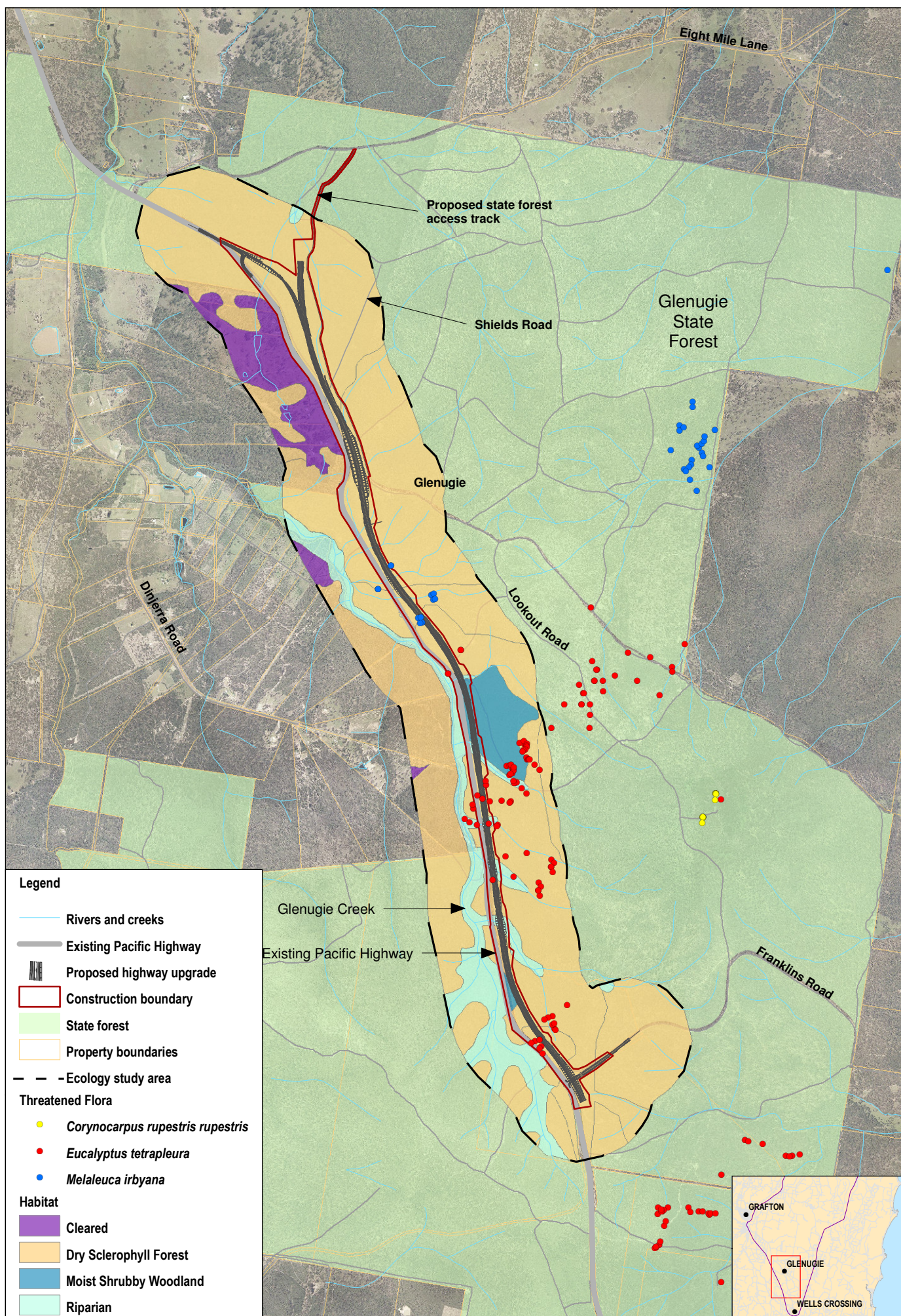
\*\* V= vulnerable. E= endangered. RoTAP= rare or threatened Australian plant.

RoTAP Codes:

2 = geographic Range in Australia less than 100km  
3 = geographic Range in Australia greater than 100km  
V = Vulnerable – at risk over longer period (20-50years)  
E= Endangered – at risk within 10-20 years.

R = Rare – uncommon plants with no current threats  
C = Reserved  
a = 1000 plants or more know from conservation reserves  
i = less than 100 plants in conservation reserves  
- = reserved population size not accurately known





Data Sources  
 Topodata: Streetworks, LPI 2008  
 Aerial: 2007

**Figure 7-1-2: Threatened flora in the study area**



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No nationally endangered ecological communities (EECs), as listed under the Commonwealth EPBC Act, are known to occur along the project corridor. One EEC listed under the NSW TSC Act occurs along the project corridor along larger watercourses. The vegetation communities within the project corridor that are consistent with this EEC are identified in **Table 7-1-3**, with locations shown in **Figure 7-1-3**.

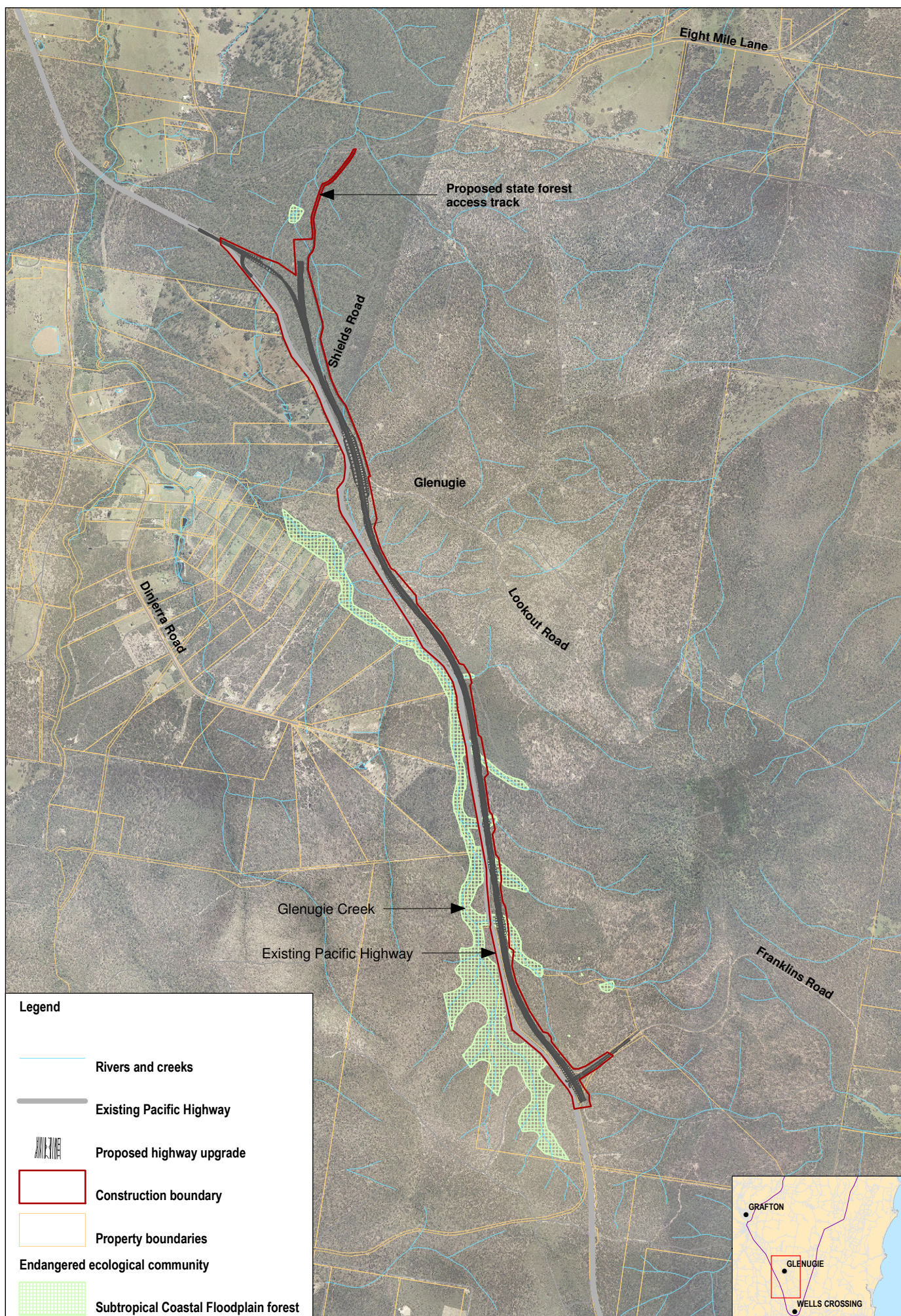
■ **Table 7 1-3 Endangered ecological communities**

Community	EEC	Habitat	Dominant species
Swamp Turpentine – Paperbark Forest	Subtropical Coastal Floodplain Forest of the NSW North Coast Bioregion	Tributaries of Glenugie Creek	<i>Lophostemon suaveolens</i> , <i>Eucalyptus resinifera</i> , <i>E. tereticornis</i> , <i>Corymbia intermedia</i> , <i>E. seeana</i> , <i>Melaleuca alternifolia</i>
Forest Red Gum – Grey Box Forest	Subtropical Coastal Floodplain Forest of the NSW North Coast Bioregion	Floodplain areas. Sandy alluvial soils.	<i>E. tereticornis</i> , <i>E. siderophloia</i> , <i>E. moluccana</i> , <i>C. intermedia</i>

### Terrestrial fauna

A total of 114 fauna species were recorded in the study area during the field surveys conducted for the project, including 65 birds, 25 mammal, 16 reptiles and eight amphibians. Additional species are expected to occur in the study area based on the habitats present and a review of records from the DECC Atlas of NSW Wildlife. The 114 fauna species recorded during field surveys included seven threatened species. These threatened fauna species are identified in **Table 7-1-4** together with additional threatened fauna species that are considered to have the potential to occur in the study area. The recorded locations of threatened fauna species are shown in **Figure 7-1-4**.





**Figure 7-1-3: Endangered ecological communities**



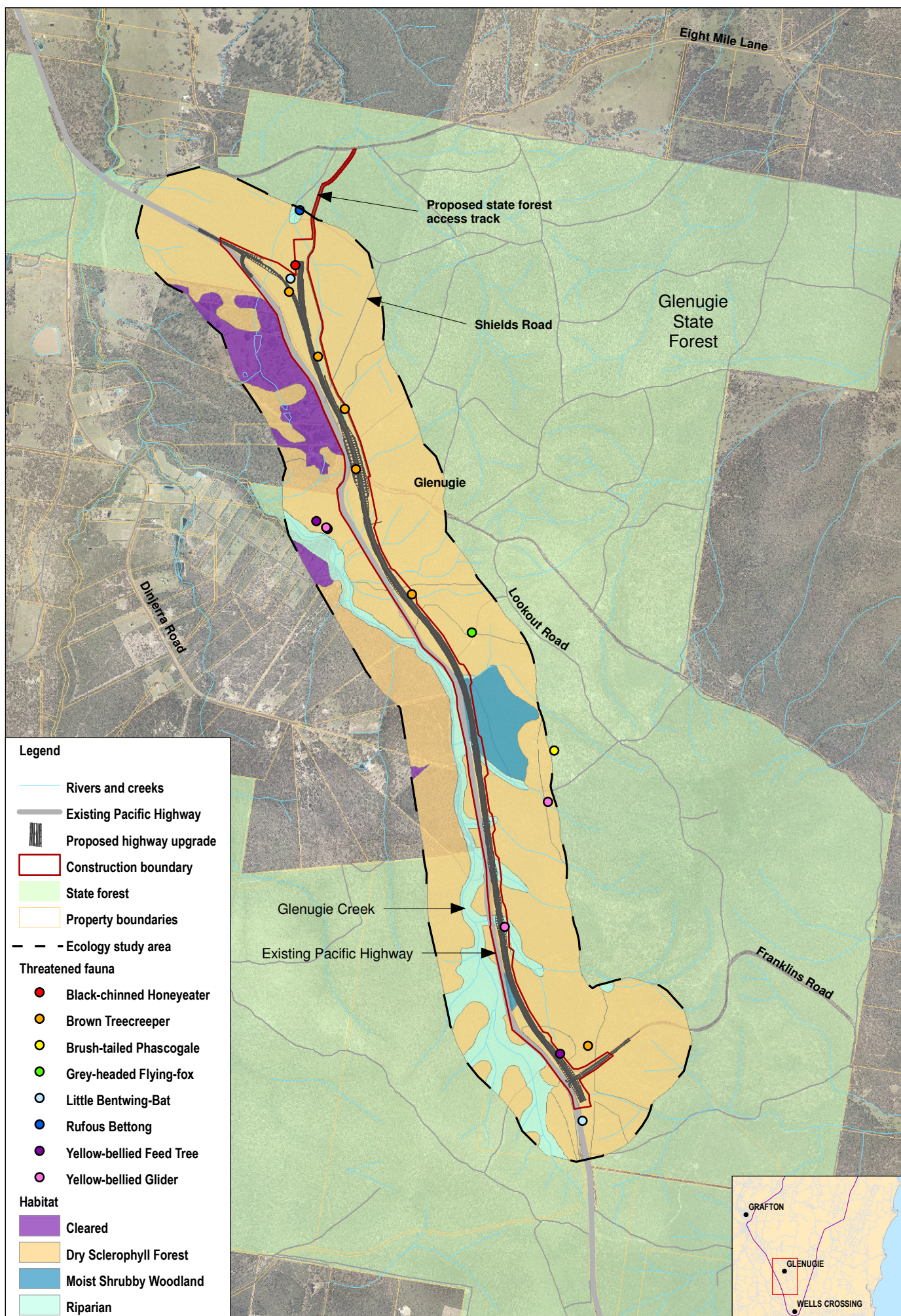


■ **Table 7-1-4 Threatened fauna species in the study area**

Species*	EPBC Act status	TSC Act status	Presence in study area
Beccari's Freetail-bat ( <i>Mormopterus beccarii</i> )	-	V	Potential
Black-chinned Honeyeater (eastern ssp.) ( <i>Melithreptus g.gularis</i> )	-	V	Confirmed
Brown Treecreeper (eastern ssp.) ( <i>Climacteris picumnus victoriae</i> )	-	V	Confirmed
Brush-tailed Phascogale ( <i>Phascogale tapoatafa</i> )	-	V	Confirmed
Bush Stone-curlew ( <i>Burhinus grallarius</i> )	-	E	Potential
Diamond Firetail ( <i>Stagonopleura guttata</i> )	-	V	Potential
Eastern Bentwing-bat ( <i>Miniopterus schreibersii oceanensis</i> )	-	V	Potential
Eastern Cave Bat ( <i>Vespadelus troungtoni</i> )	-	V	Potential
Eastern False Pipistrelle ( <i>Falsistrellus tasmaniensis</i> )	-	V	Potential
Eastern Freetail-bat ( <i>Mormopterus norfolkensis</i> )	-	V	Potential
Eastern Long-eared Bat ( <i>Nyctophilus bifax</i> )	-	V	Potential
Glossy Black-cockatoo ( <i>Calyptorhynchus lathamii</i> )	-	V	Potential
Greater Broad-nosed Bat ( <i>Scoteanax rueppellii</i> )	-	V	Potential
Grey-headed Flying Fox ( <i>Pteropus poliocephalus</i> )	V	V	Confirmed
Grey-crowned Babbler (eastern ssp) ( <i>Pomatostomus t.temporalis</i> )	-	V	Potential
Hoary Wattled Bat ( <i>Chalinolobus nigrogriseus</i> )	-	V	Potential
Hooded Robin ( <i>Melanodryas cucullata</i> )	-	V	Potential
Koala ( <i>Phascolarctos cinereus</i> )	-	V	Potential
Large-eared Pied Bat ( <i>Chalinolobus dwyeri</i> )	V	V	Potential
Large-footed Myotis ( <i>Myotis adversus</i> )	-	V	Potential
Little Bentwing-bat ( <i>Miniopterus australis</i> )	-	V	Confirmed
Masked Owl ( <i>Tyto novaehollandiae</i> )	-	V	Potential
Powerful Owl ( <i>Ninox strenua</i> )	-	V	Potential
Regent Honeyeater ( <i>Xanthomyza phrygia</i> )	E	E	Potential
Rufous bettong ( <i>Aepyprymnus rufescens</i> )	-	V	Confirmed
Speckled Warbler ( <i>Pyrholaemus sagittatus</i> )	-	V	Potential
Spotted-tailed Quoll ( <i>Dasyurus maculatus maculatus</i> )	E	V	Potential
Square-tailed Kite ( <i>Lophoictinia isura</i> )	-	V	Potential
Swift Parrot ( <i>Lathamus discolor</i> )	E	E	Potential
Yellow-bellied Glider ( <i>Petaurus australis</i> )	-	V	Confirmed
Yellow-bellied Sheathtail-Bat ( <i>Saccolaimus flaviventris</i> )	V	V	Potential

\* Either recorded or predicted to occur in the study area.





Data Sources  
 Topodata: Streetworks, LPI 2008  
 Aerial: 2007

**Figure 7-1-4: Threatened fauna in the study area**



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 A4 1:40,000 Kilometres



## Aquatic flora and fauna

The project is located within the catchment of Glenugie Creek. A Bionet search for species of fish protected under NSW legislation was conducted for the Wells Crossing to Iluka Road aquatic ecology assessment. Three listed threatened species of freshwater fish are known to occur in the region, namely Oxleyan Pygmy Perch (*Nannoperca oxleya*), Eastern Freshwater Cod (*Maccullochella ikei*) and Purple-spotted Gudgeon (*Morgurnda adspersa*). Other species likely to occur in the region which are not listed under NSW legislation but should still be considered as ecologically significant are the eastern population of the Olive Perchlet (*Ambassis agassizii*) and the Freshwater Catfish (*Tandanus tandanus*). No endangered populations or endangered ecological fish communities as listed under Schedule 4 of the FM Act 1994 are known to occur within the study area.

An aquatic ecology survey was undertaken to collate information on fish and macro-invertebrates and to assess the likely significance of impacts of the project. A description of the aquatic fauna sampling sites used for the project is provided in **Table 7-1-5**. At the time of sampling, all sites had very little flow and were turbid.

■ **Table 7-1-5 Description of aquatic fauna sampling sites**

Site	Description	Characteristics
1	Glenugie Creek at Six Mile Lane Crossing	Submerged logs and aquatic macrophytes including Milfoil ( <i>Myriophyllum</i> sp.) and Pondweed ( <i>Potamogeton</i> sp.) occur throughout the site. Site 1 was classified as Class 2 moderate fish habitat <sup>1</sup> .
2	Glenugie Creek at the northern end of the existing highway crossing	The riparian zone is densely vegetated and contiguous with upstream and downstream riparian areas. Macroinvertebrate and fish habitat is present throughout the site including aquatic macrophytes ( <i>Eleocharis</i> sp.) and submerged woody debris. Site 2 was classified as Class 2 moderate fish habitat <sup>1</sup> .
3	Glenugie Creek, 1 km south of Shields Road	Both banks are densely vegetated with overhanging <i>Lomandra longifolia</i> . Minimal submerged logs were observed at the site and no aquatic macrophytes were present when the site was surveyed. Site 3 was classified as Class 2 moderate fish habitat <sup>1</sup> .
4	Glenugie Creek, 2 km north of Franklins Road	The site is densely vegetated, with <i>Lomandra longifolia</i> overhanging the stream channel. Minimal aquatic macrophytes and submerged logs were present at the site. Site 4 was classified as Class 2 moderate fish habitat <sup>1</sup> .

A total of seven aquatic species were recorded at the sites, including Freshwater Yabbie (*Cherax destructor*), Flathead Gudgeon (*Philypnodon grandiceps*), Firetail Gudgeon (*Hypseleotris galii*), Striped Gudgeon (*Gobiomorphus australis*), Short Finned Eel (*Anguilla australis*), Long Finned Eel (*Anguilla reinhardtii*), Short Neck Turtle (*Emydura macquarii*) and Olive Perchlet (*Ambassis agassizii*). Although not protected under NSW legislation, the Olive Perchlet (*Ambassis agassizii*) recorded at site 2 is considered to be ecologically important by the Australian Society for Fish Biology.

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<sup>1</sup> Fairfull and Witheridge (2003)

The creeks and watercourses crossed by the project do not include any areas of habitat type for the Oxleyan Pygmy Perch (*Nannoperca oxleyana*), Purple-spotted Gudgeon (*Morgurnda adspersa*) and the Eastern Freshwater Cod (*Maccullochella ikei*). Aquatic habitats in the project footprint generally consist of shallow disconnected pools with limited aquatic vegetation and submerged logs, primarily with soft clay and sand substrates. In general the fragmented nature, highly variable flow rate and limited habitat refuge of the aquatic habitats in the project corridor provides little suitable habitat for most native fish species.

### **Habitat connectivity**

The entire highway alignment is located within a portion of Glenugie State Forest. The total area of Glenugie State Forest is 3,400 hectares and has been identified as a 'key habitat' as a result of this study. The State Forest provides a connecting link from the coast via Newfoundland State Forest and Yuraygir National Park through to the west into Bom Bom State Forest and dry open forest habitats on freehold land in the Coutts Crossing and Shannondale areas (refer **Figure 7-1-5**). At the north-eastern end the forest there are fragmented links to Sandy Crossing, which connects to the Pillar Valley range.

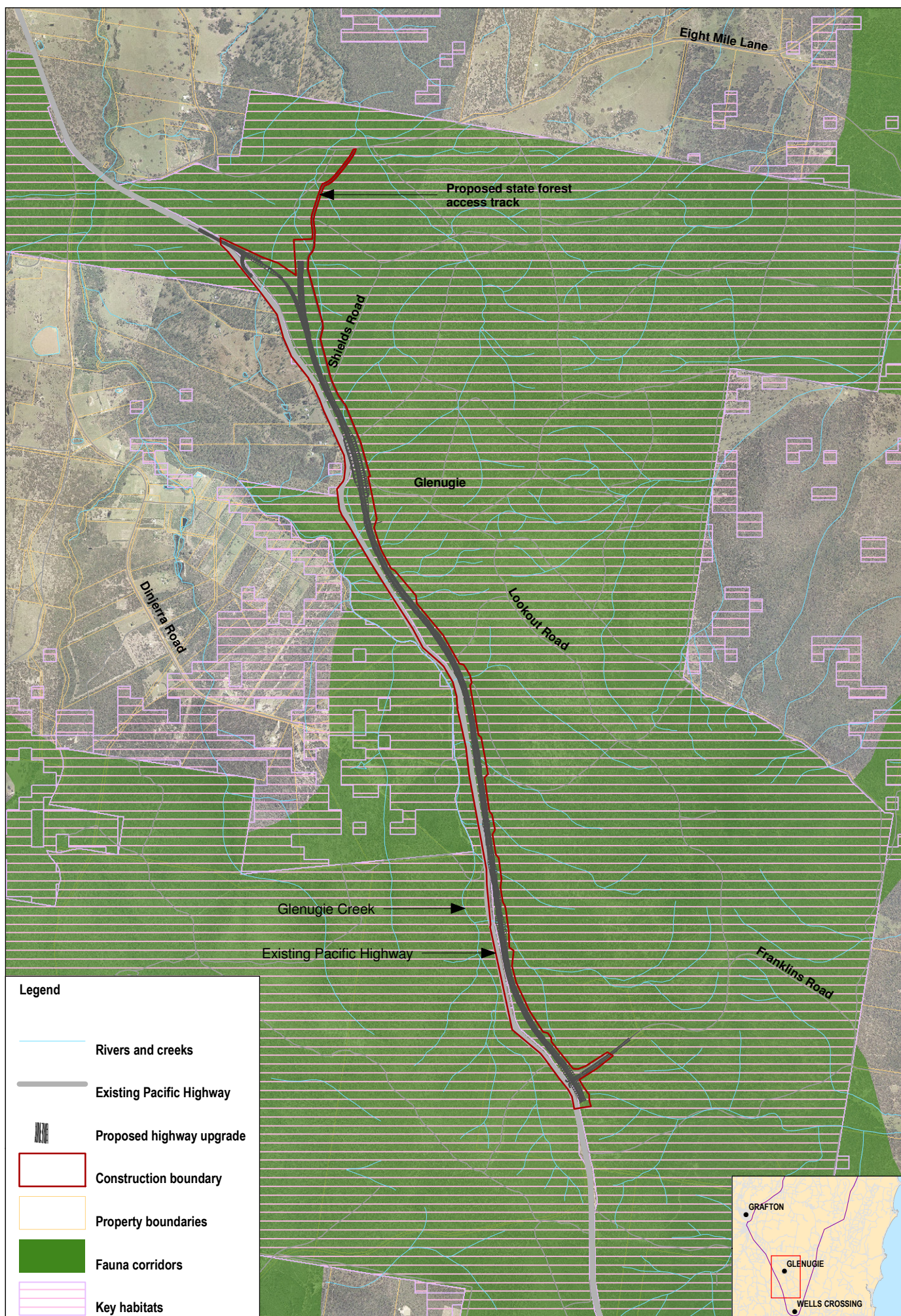
The network of key habitats and habitat fragments in the region south and east of Grafton indicate that the project study area is well connected. This fact, combined with the high diversity of flora and fauna in the region, illustrates the importance of maintaining connectivity and minimising the potential barrier effect of the project through appropriate impact mitigation measures. The review of key habitats, corridors and habitat patch network undertaken for the project was used to develop appropriate specifications for the type and location of proposed fauna crossing structures within the final road design.

### **Vegetation condition assessment**

A vegetation and habitat condition assessment was conducted for the project area. The assessment was based upon past experience and available tools to provide an indicative measure of habitat condition for each of the vegetation types impacted by the project. Features examined included the type and distribution of plant communities, floristic diversity, vegetation structure, and density of fauna habitat features.

All the vegetation types in the study area are considered of high conservation value in the region, as determined by the moderate to high plant species richness, structural diversity and presence of important habitat features for fauna (i.e. cover and shelter and foraging resources). The other contributing factor to the high condition of the vegetation and habitat is the large size of the habitats represented and degree of connectivity within the landscape including links with conservations reserves.





Data Sources  
 Topodata: Streetworks, LPI 2008  
 Aerial: 2007

**Figure 7-1-5: Key habitats and corridors**



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Vegetation condition ranking varied across the vegetation types, with the highest values being represented in the riparian communities where large mature trees and tree hollows are abundant. The Spotted Gum / Ironbark and Grey Box communities recorded lower vegetation condition rankings, reflecting timber harvesting activities, reduced tree hollow abundance and simplification of the habitat structure.

Despite the logging operations in Glenugie State Forest, the overall vegetation in the study area is relatively diverse and is of high conservation value.

### 7.1.2 Potential impacts of the project

The potential impacts on ecology have been assessed for the full motorway style upgrade, which represents the maximum extent of vegetation and habitat clearing and disturbance that would occur as a result of the project. The assessment covered all project elements, as described in Chapter 4, including the proposed forestry service road (refer to **Figure 4-1a-c**).

#### Overall vegetation and habitat loss

The direct impacts on vegetation and habitats resulting from the project, based on the proposed road corridor width for the full motorway style upgrade (with a 10 metre buffer), are detailed in **Table 7-1-6**.

■ **Table 7-1-6 Direct impacts on vegetation, fauna habitat and threatened species**

Vegetation community	Area/estimated number of individuals impacted
<b>Vegetation communities</b>	
Spotted Gum - Broad-leaved Ironbark Open Forest	33.7 ha
Spotted Gum - Square-fruited Ironbark Open Forest	21.7 ha
Grey Box - Spotted Gum Open Forest	19.2 ha
Scribbly Gum - Bloodwood Open Forest	0.00 ha
Swamp Turpentine - Paperbark Riparian Forest	5.3 ha
Narrow-leaved Red Gum - Paperbark Open Woodland	5.1 ha
Forest Red Gum - Grey Box Forest	0.00 ha
<b>Endangered ecological communities</b>	
Subtropical Coastal Floodplain Forest	5.3 ha
<b>Threatened flora species</b>	
<i>Eucalyptus tetrapleura</i>	36 ha / 6,156 individuals
<i>Melaleuca irbyana</i>	3.00 ha / 5 -10 individuals
<b>Fauna habitat</b>	
Dry sclerophyll forest	74.7 ha
Riparian forest	5.3 ha
Moist shrubby woodland	5.1 ha
<b>Total impact vegetation / habitat removal</b>	<b>85 ha</b>

There is potential for indirect impacts such as edge effects, runoff and weed

invasion to impact retained areas of vegetation/habitat adjacent to the project, as well as impacts from habitat fragmentation affecting wildlife corridors used by local threatened fauna species and loss of biological and genetic diversity.

### **Loss of endangered ecological communities**

There would be a loss of 85 hectares of vegetation as a result of the project. Approximately 5.3 hectares (6.2 per cent) of this comprises an EEC listed under the TSC Act, namely *Subtropical Coastal Floodplain Forest*. The loss that would result from the project represents a relatively small proportion of the total remaining area of this EEC in the local area (approximately 2,211 hectares in a 10 km radius).

### **Loss of threatened species and their habitat**

The impact on threatened flora and fauna species was assessed using the *Draft Guidelines for Threatened Species Assessment* (Part 3A) (DEC and DPI 2005) for species listed under the *Threatened Species Conservation Act 1995* and the *Significant Impact Guidelines – Matters of National Environmental Significance* (DEH 2006) for species listed under the EPBC Act. **Table 7-1-7** provides details of the potential impacts on the threatened flora and fauna.

■ **Table 7-1-7 Threatened species assessment of significance summary**

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Threatened flora			
Square-fruited Ironbark <i>Eucalyptus tetrapleura</i>	V	V	<ul style="list-style-type: none"><li>■ There are about 6,156 individuals within the project footprint occurring within about 36 ha of habitat.</li><li>■ The 147,000 individuals that are estimated to be present within 6 km of the project footprint could be considered to be within the local population of the study area considering the high mobility of some pollinator species (such as insects, birds and bats) and wind dispersal of pollen.</li><li>■ The total population is estimated to be between 170,000 and 250,000 individuals based on recorded locations to date and regional records (DECC 2009) comprising 50 or more different sub-groups.</li><li>■ The potential removal of <i>E. tetrapleura</i> is estimated to constitute about 4.2 per cent of the local population and between 3.6 per cent and 2.5 per cent of the total known population.</li><li>■ The project is unlikely to significantly impact the local gene pool or lead to inbreeding depressions due to fragmentation, as only a small proportion of the population would be impacted.</li><li>■ Habitat for pollinator species would be removed, however sufficient habitat for large populations of potential pollinator species would remain in surrounding areas.</li><li>■ <i>E. tetrapleura</i> is towards the southern end of its known distribution with known populations present about 12.5 km to the east and 30 km to the west and there are records (DECC 2009) about 14 km to the south and 70 km to the north.</li><li>■ There is potential for the project to alter hydrological and nutrient regimes and contribute to further weed invasion in adjacent areas of habitat by creating edge effects, however measures would be implemented to limit these impacts.</li><li>■ The RTA will develop a biodiversity offset strategy in consultation with DECC and DEWHA. This strategy will aim to maintain or improve biodiversity values in the project area in the long-term, including populations of <i>E. tetrapleura</i>.</li></ul>

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Weeping Paperbark <i>Melaleuca irbyana</i>	-	E	<ul style="list-style-type: none"> <li>■ A small population of <i>Melaleuca irbyana</i> was recorded in the study area comprising about 31 individuals of which up to 10 may be impacted, however there is potential to retain more individuals adjacent to the project footprint and reduce the impacts to 5 individuals.</li> <li>■ The local population for <i>Melaleuca irbyana</i> is considered to extend beyond the study area due to the high mobility of potential pollinator species and wind dispersal of pollen.</li> <li>■ A population of <i>Melaleuca irbyana</i> has been identified in the local records (DECC 2009) 2.5 km to the north east of the project footprint and could be considered to be part of the local population.</li> <li>■ The total local population size is estimated to be as large as 145 individuals, therefore potential impacts comprises between 3 and 7 per cent of the local population.</li> <li>■ The project would potentially remove between 16 and 32 per cent of the sub-population in the project footprint which is considered a relatively significant removal, however these impacts can potentially be mitigated.</li> <li>■ The project would result in the removal of about 3 ha of known <i>Melaleuca irbyana</i> habitat, from the 17 ha of habitat estimated to be present in close proximity to the project footprint.</li> <li>■ The study area represents the known southern extent of the species, with records present about 5 km to the south and 12 km to the west of the project footprint and to the north in the Pillar Valley area.</li> <li>■ The project would result in the sub-population within the project footprint to fragmented, as individuals would be retained on either side of the project.</li> <li>■ There is potential for the project to alter hydrological and nutrient regimes and contribute to further weed invasion in adjacent areas of habitat through creating edge effects however mitigation measures would be implemented to limit these impacts.</li> <li>■ To mitigate the loss of individuals within the project footprint and prevent significant losses to the local gene pool, it is proposed that a seed collection and propagation program be implemented for <i>Melaleuca irbyana</i>. Individuals impacted by the from the project will be translocated into adjacent habitats within the road boundary.</li> </ul>
Threatened fauna			

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Swift Parrot and Regent Honeyeater	E	E	Both species are regarded as winter-visitors to this region, and their presence in the study area would depend primarily on the flowering of Large-leaved Spotted Gum ( <i>Corymbia henryi</i> ) provide a nectar resource. The study area would constitute non-breeding habitat for a proportion of the population of both species. The study area is considered only a very small proportion of the potential foraging habitat available in eastern Australia and not an important or critical area of habitat.
Grey-headed Flying-fox	V	V	The project would clear about 85 ha of potential foraging habitat for this species. This represents a relatively minor impact for this species in the local area. In relation to the available habitat in adjacent land surrounding the highway, the project is not considered likely to affect this species at the local or regional level. The proposed action would not result in a decrease in the size of the local population nor impact on a known roost site.
Spotted-tailed Quoll	E	V	The project would remove potential habitat for the species and its prey. There is sufficient extent of comparable habitats in the locality to maintain populations and the potential for impact would occur as a result of further fragmentation of its habitat in the region, a known threat to the species. This is due to the large home range of the species and dependence on maintaining movement opportunities. Measures to preserve the habitat connectivity for this species have been incorporated into the project. Therefore breeding, foraging and movement life-cycle opportunities would remain in the region and likely to sustain a local population.
Square-tailed Kite	-	V	No nest sites were located along the proposed alignment during the surveys nor have been reported in the vicinity of the route in the local State Forests. Further surveys are recommended immediately prior to construction. The project would not impact on breeding activities of local populations of the square-tailed kite. Potential habitat for foraging and roosting is very common and widespread for this species in the region and the impacts on this life-cycle activity is expected to be minimal.
Tree-roosting Bats	-	V	Important life-cycle activities include roosting and breeding and are typically associated with tree hollows as well as foraging for insect prey which occurs in a variety of habitat types. The size of local populations is not known, although expected to be moderately large given the expanses of suitable habitat. The project would involve clearing of habitat trees and foraging habitat. Comparable habitats are very well represented throughout the locality and regional area and it is unlikely that the project would have a significant impact on the foraging or roosting life-cycle events for local populations of these bat species and continued presence in the locality could be expected.



Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Glossy Black-cockatoo	-	V	The abundance of food resources and distributional range of regional records suggests there is a widely dispersed population and individuals would be adapted to moving across modified landscapes to access food resources. The project is unlikely to significantly impact on this situation, despite the loss of food resources. There is potential to remove large hollow-bearing trees which may currently or potentially provide nest sites. These are an uncommon feature in the landscape as a result of the historical land uses. Further surveys of habitat trees have been recommended as a component of the CEMP (and FFMP) which would be particularly important if construction commences between April and June.
Koala	-	V	No evidence of koala population in the study area. The project would remove potential habitat for the species through the clearing of vegetation communities containing identified food tree species. The impact of this activity on the local population is likely to be minimal as suitable food resources are common and widespread in the region particularly to the northwest of the route and there is little evidence to suggest that koala populations or movements occur in the study area. The inclusion of fauna exclusion fencing and fauna underpasses would further minimise impacts in indeed koalas do occur.
Brush-tailed Phascogale	-	V	Evidence of local population in the study area confirmed. Suitable habitat is widespread and particularly well represented in the region. The project would remove hollow-bearing trees suitable as nesting / sheltering sites for the species and lead to further fragmentation and reduction of mature forest from the region. Suitable habitat is widespread and common providing continued habitat for local populations.
Cave-roosting bats	-	V	No caves or abandoned mine shafts have been recorded in the proposed route corridor and the project is not expected to impact on the roosting life-cycle activities of these species. The location of any roost sites for these species in the regional area is not known. The project would remove about 85 ha of forest habitat and which provides known and potential foraging habitat. Comparable habitats are very well represented throughout the locality and regional area and it is unlikely that the project would have a significant impact on the foraging life-cycle events for a local population of these bat species and continued foraging over the site and adjacent lands could be expected.

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Large forest owls	-	V	As the incidence of potential roost / nest hollows in the study area is very minimal it is considered unlikely that the project would constitute a significant impact on local populations of these species. The removal of 85 ha of forest habitat would impact on the habitat of prey species for these owls and increase fragmentation which may have an impact on juvenile dispersal and establishment of new pairs. Given the paucity of records, long home range size and the low incidence of potential roost / nest hollows in the study area the project is considered unlikely to impose a significant impact on local populations of these species.
Yellow-bellied glider	-	V	Yellow-bellied Gliders were reported on both the eastern and western side of the existing Pacific Highway from this study and large areas of suitable habitat occur to the west of Glenugie Creek. The project is likely to remove a number of den trees and sap feed trees, particularly in riparian areas. Potential den sites also occur outside the road footprint particularly along riparian areas and the loss would be a percentage of the tree hollows available. The identified preferred feed tree species in the study area are also common and widespread, particularly Grey Box ( <i>Eucalyptus moluccana</i> ), which occur throughout Glenugie State Forest. The lifecycle activities of the local population rely on the presence of den trees (mostly located in riparian areas), the presence of feed trees and habitat connectivity to access these and for social interaction. The proposed road would increase the degree of fragmentation between groups occurring east and west of the footprint. It is likely that populations would remain stable in these locations given the extent of suitable habitat however it would be desirable to mitigate the effect of fragmentation from the project on this species through the addition of canopy crossing at appropriate locations. This measure has been included in the fauna mitigation strategy for the project.

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Bush Stone-Curlew		E	<p>Potential habitat in the study area would be associated with Spotted Gum / Ironbark / Grey Box open forest, which occupies a large part of Glenugie State Forest and surrounding areas. The project would remove 74.7 ha of open forest and 5.1 ha of woodland. The exact proportion of this that is preferred habitat for this species (i.e. open grassy understorey) has not been quantified although is expected to be up to 30 ha. There are no data to confirm the current presence or status of the species in Glenugie State Forest or the number of pairs. It is considered, however, that the loss of vegetation has the potential to remove shelter and foraging resources for this species. The number of animals potentially affected in relation to the size of local and regional populations is not known, however records are widespread and it could be reasonably expected that the proportion of the population impacted would be minor and that the project would not have a significant impact on the population as a whole. Potential habitat would remain throughout Glenugie State Forest outside the project area and purpose built fauna crossing structures have been included in the project to minimise barrier effects for this species.</p>
Rufous bettong	-	V	<p>The species is found in sparsely grassed, lightly timbered open forest and woodland and favours an open grassy understorey and a high diversity of groundcover flora associated with its dietary needs. The association with riparian areas in the study area may be related to the groundcover flora diversity and density of logs or Blady Grass (<i>Imperata cylindrica</i>) for shelter and nesting.</p> <p>The project would remove 85 ha of open forest vegetation and 5 ha of riparian vegetation. The loss would likely impact on the home range territory of a small number of animals, remove a percentage of the shelter and foraging resources for these animals and potentially disrupt a breeding season. The number of animals affected in relation to the size of local population is not known. Given the widespread occurrence of DPI and DECC Atlas of NSW Wildlife for this species in the locality it could be reasonably expected the proportion to the population impacted would be minor and not lead to a significant impact on the population as a whole.</p> <p>Measures to mitigate the effects of fragmentation have been considered in the design and placement of fauna underpass structures aimed at facilitating crossing of the highway to access available habitat and allow genetic exchange. Suitable habitat is widespread and common providing continued habitat for local populations.</p>

Species	Conservation status		Summary of assessment
	EPBC Act	TSC Act	
Woodland birds and Bush stone-curlew	-	V	The project would remove about 85 ha of open forest, which is potential habitat for these birds. The loss would likely remove a percentage of the shelter and foraging resources for these birds and potentially disrupt a breeding season. The number of birds affected in relation to the size of local populations is not known, however records are widespread and it could be reasonably expected the proportion of the populations impacted would be minor and not lead to significant impacts on populations as a whole.

### Loss of habitat for migratory species

No migratory bird species listed under the EPBC Act were identified during the field investigation conducted for the project. While the Regent Honeyeater (*Xanthomyza phrygia*) and White-throated Needletail (*Hirundapus caudacutus*) are considered to potentially occur, the study area (including the project footprint) does not contain important foraging or breeding habitat for either of these species.

### Habitat fragmentation

Habitat fragmentation is the division of a single (contiguous) area of bushland into two or more areas. This has the potential to disrupt wildlife movement, isolate flora and fauna populations and corresponding genetic exchange, decrease the available area of habitat, and increase edge effects. Large areas of continuous habitat are particularly important for species that have large habitat ranges, such as Spotted-tail Quoll (*Dasyurus maculatus*) and Large Forest Owls. For these species, larger habitat areas are more likely to provide suitable roosting and nesting sites and food resources, and hence are able to support larger populations, which in turn favours population survival as the chances of finding a mate are increased. Large areas of contiguous vegetation also decrease the likelihood of local extinctions from stochastic events such as wildfire and disease, as individuals can repopulate an area more effectively. Potential impacts from habitat fragmentation include alteration of hydrology and siltation of aquatic habitats, impacts on species with localised habits, edge effects and barrier effects.

The landscape surrounding the study area supports several very large areas of habitat associated with Glenugie State Forest, Newfoundland State Forest, Yuraygir National Park and natural vegetation on private rural properties. The habitat to the west of the project becomes increasingly more fragmented in lower elevated lands and private property while Glenugie State Forest continues extensively to the east of the project. The project would have the greatest potential impact on ground-dwelling terrestrial fauna and species with large home-ranges such as the Spotted-tailed Quoll. Mobile species such as bats and birds have the ability to move across the landscape and access the habitats fragmented by the road.

Measures to reduce the impact on connectivity have been considered in the

development of a fauna crossing strategy (Section 7.1.3) and include the provision of dedicated and combined fauna underpass structures, canopy rope structures and fauna exclusion fencing. These features have been strategically located at important habitat areas and linkages in the landscape that reflect the habitat assessment data and predicted distribution of threatened fauna.

### **Edge effects and weed infestation**

Fragmented habitats are also subject to potential edge effects, which can include increased fauna mortality during construction. In the long-term, fragmented habitats may lead to modified animal behaviour, a modified physical and chemical environment and a spread of exotic species. Edge effects are expected to be greatest where the project would create 'new' edges through Glenugie State Forest. Edge effects would be greatest on the eastern edge of the project footprint as these areas would be relatively unaffected by the edge effects of the existing highway. The extent of possible edge effect impacts has been estimated at 40 ha based on a 50 m wide zone of potential edge effects on the eastern side of the project corridor.

Riparian vegetation communities (many of which are the Subtropical Coastal Floodplain Forest endangered ecological community) are most likely to be impacted by edge effects where invasive weed species such as *Lantana camara* are present. The spread of *Lantana camara* is likely to be favoured where clearing and edge effect result in greater light availability. Furthermore, the spread of this weed species may result in shading of native understorey species and alter the nature of fauna habitats. *Melaleuca irbyana* retained in habitats adjacent to the project are likely to be impacted from edge effects, including competition with weed species and changes to physical attributes such as sunlight, hydrological regimes and soil nutrients.

Edge effects can potentially be reduced through general impact mitigation and rehabilitation measures that aim to control surface water run-off into adjacent remnant vegetation. Dense roadside plantings using a diversity of local indigenous plant species would reduce the potential for weed spread into disturbed edge habitats.

### **Impacts on fauna movements and behaviour**

Wildlife corridors play an important role for conservation of biodiversity as they allow for migration and dispersal of plants and animals, reduce competition, provide refuge, and provide important movement pathways for maintaining genetic diversity in populations. Corridors are particularly important in fragmented and agricultural areas as they provide pathways for movement of fauna species that are reluctant to move through cleared landscapes.

Glenugie State Forest provides a connecting link from the coast via Newfoundland State Forest and Yuraygir National Park through to the west into Bom Bom State Forest and dry open forest habitats on freehold land in the Coutts Crossing and Shannondale areas. At the north-eastern end of the forest there are fragmented links to Sandy Crossing that link to the Pillar Valley range. Given the expanse of habitat surrounding the study area, specific linear wildlife corridors are very limited. The only identifiable corridor occurs

immediately north of the project site, traversing east-west from Glenugie State Forest and adjoining the southern end of Eight Mile Lane. This corridor would not be directly impacted by the project.

The network of key habitats and habitat fragments in the region south and east of Grafton indicate that the Glenugie study area is well connected. The high diversity of flora and fauna in the region illustrates the importance of maintaining connectivity and minimising the potential barrier effect of the project through appropriate impact mitigation. Additionally, by increasing the road network and traffic volumes in the locality, the project would indirectly increase fauna mortality and injuries from collisions with vehicles. The significance of this impact on local populations is difficult to determine given the existing network of roads including the existing highway which is currently impacting on populations. Fauna crossing structures, exclusion fencing and signage have been proposed to minimise this impact and consideration of the number and location of these has been incorporated into the project in Section 7.1.3.

The Mid North Coast Regional Strategy (DoP 2009a) identifies Glenugie State Forest as a key area by linking it, via regional and sub-regional corridors, with Newfoundland State Forest and Yuraygir National Park to the east and to the northeast with Sandy crossing and the Pillar Valley range. These links are consistent with other local and regional corridors identified by DECC (2003). By following the existing Pacific Highway through Glenugie the proposed upgraded does not directly impact on a regional or sub-regional corridor. However the project's impact of further widening the existing highway corridor and fragmentation of habitat at this location has been identified and addressed in the development of appropriate impact mitigation measures designed to facilitate fauna movement.

### **Impacts on riparian habitats**

Riparian habitat in the study area is restricted to very narrow linear strips of vegetation, less than 100 m wide, along Glenugie Creek and associated tributaries which are distinctive from the surrounding dry open forest. Impacts on riparian vegetation would occur directly in the project corridor at proposed creek crossing locations. Indirect impacts would occur through changes to local hydrological regimes and edge effects including possible shading or proximal vegetation and potential weed invasion. Approximately five hectares of riparian habitat would be directly removed as a result of the project. Impacts on riparian habitats would be mitigated through minimising the construction footprint at all proposed creek crossings, installing run-off storage structures, minimising erosion and the post-construction rehabilitation of the area through plantings of locally indigenous riparian species.

### **Impacts on aquatic habitats**

The creeks and watercourses in the study area do not include any areas of habitat type for the Oxleyan Pygmy Perch (*Nannoperca oxleyana*), Eastern Cod (*Marccullochella ikei*) and Purple-spotted Gudgeon (*Morgurnda adspersa*). Potential impacts on aquatic habitats include overshadowing, pollution of waterways, change to the hydrological regime, and removal of in-stream woody debris. The activities with the potential to impact aquatic

flora and fauna during construction and operation include:

- Removal of in-stream woody debris (snags) which is listed as a key threatening process under the FM Act as it can provide crucial habitat to juvenile fish, macroinvertebrates and other aquatic organisms.
- Changes to the provision of aquatic habitat, water quality and natural flow regimes that can favour exotic species.
- Predation by exotic species, in particular the Plague Minnow (*Gambusia holbrooki*), which is listed as a key threatening process under the FM Act.
- Increased sedimentation and erosion during construction which is considered a threatening process under the FM Act.
- Increased suspended solids which could impact fish and macroinvertebrate abundance through clogging gill structures and benthic smothering.
- Increased particulates in the water column that can reduce water infiltration which may limit plant growth and influence predator foraging behaviour.
- Increased road runoff and pollutants entering the waterways which could have a toxic effect on aquatic habitats and biodiversity. Pollutants include nutrients, heavy metals, pesticides, herbicides and petroleum hydrocarbons.
- Installation of in-stream structures such as pylons is listed as a key threatening process under the FM Act. Culverts and causeways can modify the natural flow of rivers by increasing, decreasing or altering the seasonality, frequency, magnitude and timing of flow which can disrupt natural reproductive cues, and natural sediment movement patterns. Culverts can also act as a physical barrier to native fish and invertebrates.

The potential for increased runoff from paved surfaces, flow concentration and stream erosion is discussed further in Section 7.2.

### Key threatening processes

The TSC Act and FM Act list key threatening processes as activities or processes that:

- Adversely affect threatened species, populations or ecological communities.
- Could cause species, populations or ecological communities that are not threatened to become threatened.

It is evident that the project would instigate some key threatening processes, such as clearing of native vegetation and removal of hollow-bearing trees. Several other processes could be reasonably expected and have been discussed in **Table 7-1-8** along with proposed measures to mitigate impacts.

■ **Table 7-1-8 Key threatening processes (KTPs) related to the project**

KTPs	Type of threat	Level of threat	Potential impacts	Mitigation measures
Invasion and establishment of exotic vines and scramblers	Weed	High	Exotic vines and scramblers were not abundant in the study area but are a potential future problem in gully areas impacted by vegetation loss and edge effects.	Weed management techniques are to be developed as part of the Construction and Operation Environmental Management Plans.
Invasion of native plant communities by Bitou Bush & Boneseed	Weed	Moderate-High	Bitou bush was recorded in moderate abundance in parts of Newry State Forest. There is potential for this species to increase in distribution and abundance.	Weed management techniques are to be developed as part of the Construction and Operation Environmental Management Plans.
Invasion of native plant communities by exotic perennial grasses	Weed	High	Several exotic perennial grasses were identified on disturbed edges of the existing highway and trails through bushland. These species are associated with edge effects.	Weed management techniques are to be developed as part of the Construction and Operation Environmental Management Plans.
Invasion, establishment and spread of <i>Lantana camara</i>	Weed	Very High	A majority of the moister vegetation communities in the study area have moderate infestations of <i>Lantana camara</i> , particularly where previous disturbances have occurred. There is a high probability that these areas would become further infested with the creation of edge effects.	Weed management techniques are to be developed as part of the Construction and Operation Environmental Management Plans.
Competition and grazing by the feral European rabbit	Pest animal	Low-Moderate	Evidence of European rabbit was recorded in the study area. The project may provide additional areas of suitable habitat for European rabbit.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Competition and habitat degradation by feral goats	Pest animal	Low	The project may provide additional areas of suitable habitat for feral goats.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.



KTPs	Type of threat	Level of threat	Potential impacts	Mitigation measures
Competition from feral honeybees	Pest animal	Low	The project may provide additional areas of suitable habitat for feral honeybees.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Herbivory and environmental degradation caused by feral deer	Pest animal	Low	The project may provide additional areas of suitable habitat for feral deer.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Importation of red imported fire ants into NSW	Pest animal	Low	It is unlikely the project could lead to the importation of red imported fire ants to the study area.	Ensuring construction equipment has been washed down before entering the project area.
Introduction of the Large Earth Bumblebee ( <i>Bombus terrestris</i> )	Pest animal	Low	It is unlikely the project could lead to introduction of the Large Earth Bumblebee to the project area.	Ensuring construction equipment has been washed down before entering the project area.
Invasion and establishment of the Cane Toad	Pest animal	Low-Moderate	The project may contribute to the invasion and establishment of the Cane Toad.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Predation by feral cats	Pest animal	Low-Moderate	The project may contribute to additional predation from feral cats, through habitat fragmentation.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Predation by the European Red Fox	Pest animal	Low-Moderate	The project may contribute to additional predation from European Red Fox, through habitat fragmentation.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Predation by the Plague Minnow ( <i>Gambusia holbrooki</i> )	Pest animal	Low-Moderate	The project may contribute to additional predation from the Plague Minnow (also known as Mosquito Fish).	None known. Difficult to prevent.

KTPs	Type of threat	Level of threat	Potential impacts	Mitigation measures
Predation, habitat degradation, competition and disease transmission by Feral Pig ( <i>Sus scrofa</i> )	Pest animal	Low-Moderate	The project may contribute to additional presence of Feral Pig in the study area through habitat fragmentation.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration.
Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands.	Habitat loss/change	Moderate-High	There is a chance the natural flow regimes of creeks, rivers, wetlands and floodplains would be altered from the project.	The project has been designed to limit alterations to natural hydrology regimes.
Bushrock removal	Habitat loss/change	Low	Significant areas of bush rock were not noted in the study area.	Where bush rocks are present in the study area these would be placed in adjacent habitats.
Clearing of native vegetation	Habitat loss/change	Very High	The project would result in the clearing of up to 85 ha of native vegetation.	Where possible vegetation clearance would be minimised.
Ecological consequences of high frequency fires	Habitat loss/change	Low-Moderate	There is evidence that State Forest areas have been impacted from high frequency fire regimes. The project is unlikely to contribute significantly to this KTP.	N/A
Human-caused Climate Change	Habitat loss/change	Moderate	The project would contribute towards human-caused climate change.	N/A
Loss and/or degradation of sites used for hill-topping by butterflies	Habitat loss/change	Moderate	It is unknown if these areas are significant for butterflies.	Where possible vegetation clearance would be minimised.
Loss of Hollow-bearing Trees – key threatening process	Habitat loss/change	High	The project would result in the clearing of hollow-bearing trees.	Where possible hollow bearing trees would be avoided.
Removal of dead wood and dead trees	Habitat loss/change	High	The project would result in the removal of dead wood and dead trees.	Dead wood and dead trees would be relocated to adjacent areas of habitat.

KTPs	Type of threat	Level of threat	Potential impacts	Mitigation measures
Infection by Psittacine circoviral (beak and feather) disease affecting endangered psittacine species	Disease	Low	It is unlikely the project would exacerbate this KTP.	Ensuring construction equipment has been washed down before entering the project area.
Infection of frogs by amphibian chytrid fungus causing the disease chytridiomycosis	Disease	Low	It is unlikely the project would significantly exacerbate this KTP.	Ensuring construction equipment has been washed down before entering the project area.
Infection of native plants by Phytophthora cinnamomi	Disease	Moderate	There is potential for this disease to be spread throughout the project area from construction machinery.	Ensuring construction equipment has been washed down before entering the project area.
Increased sedimentation and erosion during construction	Habitat loss/ change	Moderate	There is potential for increased sedimentation to result due to the construction process.	The project has been designed to minimise any bank erosion or increased sedimentation.
Increased pollution	Habitat loss/ change	Moderate	The project may result in a slight increase in road runoff and associated pollutants entering waterways during construction and operation.	Runoff and associated pollutants should be limited with sufficient mitigation strategies in place.
Removal of instream woody debris	Habitat loss/ change	High	The project would result in the removal of instream woody debris.	Instream woody snags would need to be relocated into adjacent areas.
Loss of aquatic and riparian habitats	Habitat loss/ change	Moderate	The project would require the removal of aquatic and riparian vegetation to accommodate new crossings.	Where possible aquatic habitat clearance would be minimised.
Predation of native fish by exotic species	Pest Animal	Low	Predation by exotic species such as Plague Minnow ( <i>Gambusia holbrooki</i> ) is most likely to occur in highly disturbed freshwater streams.	Disturbances to water quality and habitat needs to be minimised and monitored where appropriate.

KTPs	Type of threat	Level of threat	Potential impacts	Mitigation measures
Installation of instream structures	Habitat loss/ change	High	The project would result in the construction of culverts which may modify the natural flow of rivers. This alteration may disrupt natural reproductive cues and natural processes of erosion and sedimentation resulting in a loss of aquatic habitat for fish and macroinvertebrates.	New watercourse crossings associated with the project need to meet NSW Fisheries Guidelines, which aim to ensure passage for aquatic biota is maintained.

### Cumulative impacts

At the landscape scale, the major potential ecological impacts of increasing road networks are disruption of landscape processes and loss of biodiversity (Forman and Alexander 1998). An extensive and complex road network already exists in the study area and the project would contribute to this network. Impacts could be offset to a degree by the development of a biodiversity offset strategy. Any efforts should be based on the objective of maintaining or improving biodiversity values in the project area in the long-term. Estimates of the total vegetation disturbance for the 13 existing Pacific Highway upgrade projects are provided in **Table 7-1-9**. The table does not include project that have been completed or are currently under construction.

■ **Table 7-1-9 Estimated vegetation disturbance**

Project name	Project stage	Project length (km)	Vegetation disturbance (ha)	EEC** disturbance (ha)
Proposed upgrade Banora Point	Project approval obtained and pre-construction activities commenced	2.5	7.7	3.82
Tintenbar to Ewingsdale	Environmental assessment completed	17	10	2
Woodburn to Ballina*	Concept design selected	36	131	56
Iluka Road to Woodburn*	Preferred concept design selected	33	Not yet available	Not yet available
Wells Crossing to Iluka Road – Glenugie upgrade	Environmental assessment commenced	7.3	85	5.3
Wells Crossing to Iluka Road (remaining) *	Concept design selected	63.6	345	55
Woolgoolga to Wells Crossing*	Concept design selected	27	230	51 (preliminary estimate)

Project name	Project stage	Project length (km)	Vegetation disturbance (ha)	EEC** disturbance (ha)
Sapphire to Woolgoolga upgrade	Project approval obtained and pre-construction activities commenced	25	83.1	18.2
Coffs Harbour Bypass*	Concept design selected	12	21	Not yet available
Warrell Creek to Urunga	Environmental assessment commenced	45	255	60.3
Kempsey to Eungai	Project approval obtained and pre-construction activities commenced	42	286	63
Oxley Highway to Kempsey	Environmental assessment commenced	37	229	66
F3 to Raymond Terrace*	Concept design selected	14	49	Not yet available
<b>Total</b>		<b>361.4</b>	Not yet available	Not yet available

\* Clearing information for these projects is based on the concept design corridor. These concept designs are based on a preliminary corridor width estimate of 150 m, which allows for refinement of the corridor during the environmental assessment phase. The final corridor widths, and associated clearing requirements, are likely to be considerably lower.

\*\* Endangered ecological community

### 7.1.3 Impact mitigation and management measures

The proposed impact mitigation and management measures detailed in this section apply to the full motorway upgrade. They also apply to the likely initial staging, except where noted.

General and specific mitigation measures and long-term management and monitoring strategies would be in accordance with the following goals:

- Maintain and protect existing biodiversity.
- Maintain and protect species and populations of National and State conservation significance.
- Maintain existing water quality and hydrological flow regimes.
- Minimise the loss of vegetation and habitat.
- Minimise pollution and degradation.
- Enable movements and dispersal of species to be maintained.
- Minimise fauna mortality and injury, and damage to individual plant species.
- Enable habitat connectivity for arboreal mammals.

These aims would form the basis of a Flora and Fauna Management Plan

(FFMP) to be prepared as a supplementary plan to the Construction Environmental Management Plan (CEMP) and the Operation Environmental Management Plan (OEMP) for the project. The RTA would be responsible for initiating management and monitoring programs associated with the proposed upgrade. These would be detailed in the FFMP and would be based on the broader management aims of the project.

### **Loss of native vegetation and fauna habitat loss**

- Installation of protective fencing to mark the limits of clearing (i.e. 'no-go' areas) so that vehicles and other activities associated with construction, such as construction compounds and stockpile sites, do not enter adjacent areas of vegetation, particularly in areas where threatened flora species and endangered ecological communities are present.
- Pre-clearance surveys would be undertaken to identify hollow bearing trees and determine trees that are possibly occupied by fauna species. During the proposed clearing works, an experienced wildlife handler should be present during vegetation removal to retrieve any displaced fauna and release into adjacent habitats safe from construction works.
- In areas where vegetation is retained, vegetation management measures would be implemented including weed removal, native plantings, broadcasting of collected native seed and re-location of specific habitat resources such as bush rocks, hollow logs, hollow tree trunks and branches.
- Cleared native vegetation would be mulched and topsoil would be collected to preserve the soil stored seed bank for re-use in rehabilitation works and erosion control. Native seed should be sourced from the road footprint and used in landscaping/ revegetation works.
- Revegetation/rehabilitation of the site should be conducted progressively during the construction to ensure use of collected topsoil and seed and to develop different successional stages of rehabilitation.
- A seed collection and propagation program would be implemented prior to construction for native flora species to be used in landscaping with a particular focus on supplementing the local populations of *Melaleuca irbyana* and *Eucalyptus tetrapleura*.
- A translocation strategy should be developed for *Melaleuca irbyana* and implemented in consultation with DECC and in accordance with relevant guidelines such as Guidelines for the Translocation of Threatened Plants in Australia (Vallee *et al.* 2004).
- Monitoring of plantings, translocated plants and rehabilitation areas should be conducted twice annually for at least two years post construction and following re-assessment of the monitoring protocols it would be decided if further monitoring is necessary.
- The habitat compensation package would be negotiated with DECC to ensure impacts to the communities area offset through protection of larger high quality areas. There is scope for rehabilitated lands and retained areas of vegetation to be included in the road boundary as part of the offset package.

### Loss of endangered ecological communities

Subtropical Coastal Floodplain Forest is present along some watercourses in the project footprint. This community is not extensive in the project footprint and clearing of these areas would be restricted to the minimum area possible. Protected vegetation outside and adjoining the construction corridor would be clearly flagged to control accidental incursions.

Habitat compensation packages would be negotiated with DECC to establish a suitable offset area possibly including areas of this EEC. Impacts on this EEC may potentially be offset through protection of larger high quality areas of this community. There is scope for rehabilitated areas and retained areas of vegetation in the road boundary to be included as part of an offset package.

### Loss of significant flora and fauna species

Measures to avoid, mitigate and offset potential impacts on threatened flora and fauna at the construction and post-construction stages of the project are outlined in **Table 7-1-10**.

#### Threatened flora

Measures to avoid, mitigate and offset the direct impacts to threatened flora species are detailed for each species in **Table 7-1-10** and include the following measures:

- Avoidance: Flagging the limits of the clearing works would be implemented along the project footprint and any areas or individual plants within the footprint which can be retained would be identified and protected. This is particularly relevant to identifying the location of *Melaleuca irbyana* and *Eucalyptus tetrapleura* adjacent to the construction corridor
- Mitigation: A rehabilitation / translocation strategy is to be prepared for *Melaleuca irbyana* as part of the FFMP. The strategy is to outline methods and timing for seed collection and propagation and dealing with cuttings and root translocation, as well as identify the planting location and maintenance and monitoring requirements. The program needs to be implemented in the project footprint prior to and during construction. The strategy should be developed in consultation with DECC and in accordance with relevant guidelines such as Guidelines for the Translocation of Threatened Plants in Australia (Vallee et. al. 2004).
- Mitigation: Specific details incorporating best-practice guidelines for seed collection and propagation and translocation of plants needs to be provided in the FFMP for the project, along with appropriate monitoring and maintenance protocols.
- Offset: A suitable offset for the project has yet to be established. Areas which support large populations of *Eucalyptus tetrapleura* and *Melaleuca irbyana* are the primary focus for establishing a suitable offset area.

While it is considered unlikely that any rare cryptic or seasonal flora species occur in the project area, additional seasonal surveys will target such species

that may occur in addition to annual species. This includes cryptic rare and threatened flora species that primarily flower during spring and summer, namely *Cryptostylis hunteriana*, *Caesia parviflora* var. *minor*, *Maundia triglochinoides*, *Centranthera cochinchinensis*, and *Tylophora woollsii*. The targeted seasonal surveys for cryptic flora would be undertaken in consultation with the DECC and DEWHA.

### Threatened fauna

Mitigation measures for threatened fauna would include many of the mitigation measures listed above under native vegetation and fauna habitat loss, including pre-clearance surveys and protocols, a fauna rescue framework for clearing works, and rehabilitation of disturbed areas and retained areas of remnant vegetation. Monitoring is required for threatened fauna, with the aim of assessing the impacts of the project on select threatened fauna species (i.e. target species) in addition monitoring the effectiveness of impact mitigation measures. Monitoring would include:

- A strategy for monitoring the Yellow-bellied Glider (*Petaurus australis*) population in the affected portion of Glenugie State Forest should be developed as part of the FFMP. Issues which should be addressed include identifying den locations and sap feeding trees, reporting on glider locations and monitoring canopy rope structures for use.
- Pre-clearance surveys are required to identify any important features for threatened fauna directly located within the road footprint so that these can be avoided during construction or timed for appropriate removal so that impacts to fauna are minimised. This includes any nests of the Square-tailed Kite (*Lophoictinia isura*), Glossy Black-Cockatoo (*Calyptorhynchus latham*) or Large Forest Owls and any den sites for the Yellow-bellied Glider (*Petaurus australis*) which may occur in the corridor.
- Routine monitoring of fauna exclusion fencing for damage and repair is to be conducted four times per year for the duration of the monitoring period.

### ■ Table 7-1-10 Avoidance, mitigation and offset measures for threatened species

Threatened species	Avoidance and impact mitigation measures
Square-fruited Ironbark <i>Eucalyptus tetrapleura</i>	<ul style="list-style-type: none"> <li>■ Within the population area of <i>Eucalyptus tetrapleura</i> the limits of the extent of clearing for the project would be clearly identified to avoid any accidental incursions or impacts to <i>Eucalyptus tetrapleura</i> and any areas or individuals trees adjacent to the project footprint with potential to be retained would be identified and protected.</li> <li>■ A suitable offset for the project will be developed in consultation with DECC and Department of Planning. Areas that support large populations of <i>E. tetrapleura</i> are the primary focus for establishing a suitable offset area.</li> </ul>



Threatened species	Avoidance and impact mitigation measures
Weeping Paperbark <i>Melaleuca irbyana</i>	<ul style="list-style-type: none"> <li>■ Flagging of <i>Melaleuca irbyana</i> plants to be retained along the edges of the project footprint would be conducted before clearing for construction and strict protocols would be implemented to avoid direct impacts where possible. In particular, several <i>Melaleuca irbyana</i> on the edge of the road batters would be protected from direct impacts.</li> <li>■ A rehabilitation/translocation strategy is to be prepared for <i>Melaleuca irbyana</i> as part of the FFMP prior to construction to supplement the local population with propagated individuals to ensure genetic diversity is maintained in this area. Planting should be implemented in suitable riparian habitat for this species immediately adjacent to the project footprint.</li> <li>■ Any <i>Melaleuca irbyana</i> within the project footprint should be translocated to adjacent areas of habitat. Translocation of <i>Melaleuca irbyana</i> is likely to be successful given appropriate preparation, management and maintenance considering the suckering habit of this species.</li> <li>■ A monitoring program would be developed to assess the health and development of transplanted individuals and supplementary plantings of <i>Melaleuca irbyana</i> in habitats surrounding the project footprint.</li> <li>■ Monitoring of plantings and rehabilitation areas should be conducted twice annually for at least two years post construction and following re-assessment of the monitoring protocols it would be decided if further monitoring is necessary.</li> <li>■ Specific details incorporating best-practice guidelines for seed collection and propagation and translocation of plants needs to be provided in the FFMP for the project, along with appropriate monitoring and maintenance protocols.</li> <li>■ A suitable offset for the project will be developed in consultation with DECC and Department of Planning.</li> </ul>
Threatened Fauna	<ul style="list-style-type: none"> <li>■ Vegetation clearing is to be strictly minimised to the required construction areas only and controlled where known populations of threatened species have been identified, particularly in riparian vegetation.</li> <li>■ Identify significant features such as 'habitat trees' (i.e. hollow-bearing trees), sap feeding trees and nest sites from the construction corridor during the pre-construction phase and avoid these features where possible during construction or during the breeding period of the affected animal.</li> <li>■ The RTA's fauna rescue framework would be used as a basis for developing a protocol for the handling and translocation of fauna during construction.</li> <li>■ Provide dedicated, combined and incidental fauna underpass structures as well as fauna exclusion fencing at key locations to target the range of large, medium and smaller species present.</li> <li>■ Provide canopy rope crossings at key locations identified to target the Yellow-bellied Glider and common glider species.</li> <li>■ Monitor fauna crossing during the operational phase of the road to determine their usage by Rufous Bettong and Yellow-bellied Gliders. As there is already a considerable amount of data on underpass monitoring for other species this precludes the need for further work on other species.</li> </ul>

### **Loss of biological diversity**

To help maintain biological and genetic diversity of fauna species, a habitat augmentation procedure is to be documented in the FFMP. This would ensure important habitat features such as hollow logs, tree hollows and bush rocks are relocated to adjacent areas of habitat. Additionally, having an ecologist supervise the clearing and habitat augmentation activities would minimise injuries to individual animals, relocating fauna to adjacent suitable habitats.

Rehabilitation would occur at roadside verges utilising local species propagated from stored topsoil collected within the project footprint and would contribute to mitigating edge effects, weed invasion and loss of genetic diversity. Topsoil with low or no weed presence should be salvaged from areas of cleared vegetation and spread in roadside verges that have similar habitat conditions as the area it was collected from. Seed collection should be undertaken after known flowering and seeding times, prior to construction, and where applicable during vegetation clearing activities, from sclerophyll species suitable for propagation and hydro-seeding in roadside verges. Where applicable, collected seed should be utilised for species which are unlikely to be present in the seed-bank of the salvaged soil, such as species from the Myrtaceae, Casuarinaceae and Proteaceae plant families. Appropriate storage of salvaged topsoil and timing for spreading in road verges needs to be resolved in the rehabilitation and weed control sections of the FFMP.

### **Management of edge effects and weed invasion**

Noxious and other weed species are not abundant within the project corridor being mainly restricted to the edges of the existing highway and some watercourses. During construction there is potential for noxious and invasive weeds to be spread via earthworks and clearing activities, from seeds and other propagules in the soil and on vegetative material. The rehabilitation and weed control strategies in the CEMP should specify measures to minimise the spread of weeds.

A rehabilitation and weed control strategy would be developed as part of the CEMP and implemented including strategies to minimise the spread of invasive weed species during construction, and ongoing maintenance and monitoring of rehabilitation areas.

Other mitigation measures used to further minimise potential impacts from edge effects include implementing adequate soil erosion and sedimentation control measures.

### **Management of habitat fragmentation and wildlife corridors**

The potential impact of the project on fauna movement and habitat connectivity has been considered in the selection and design of fauna crossing structures. The concept design for the project incorporates:

- Dedicated and incidental fauna underpass structures at important open forest and riparian locations (**Table 7-1-11**).
- Dedicated rope overpasses at strategic locations for arboreal fauna (**Table 7-1-12**).

These fauna crossing structures would be incorporated into the project as part of both the full motorway style upgrade and the likely initial staging. The proposed fauna crossings listed in **Table 7-1-11** and **Table 7-1-12** are indicative only. The final details of fauna crossings will be confirmed in the detailed design phase of the project in consultation with the DECC and DPI.

**Table 7-1-11** refers to the following three types of underpass structure which are defined as:

- **Dedicated Fauna structure:** A structure that is included for the specific purposes of fauna use only and not drainage or dual purpose.
- **Combined fauna structure:** A culvert or pipe structure placed in a drainage area that has a dual purpose of facilitating fauna use via the inclusion of special features such as a raised bench or lowered central floor for elevated dry passage or a raised out cell which would not be filled with water during normal rainfall events but which takes flow during heavy rainfall.
- **Incidental fauna structure:** a drainage structure such as a culvert or pipe that is considered large enough to accommodate fauna use and is located in a bushland area or corridor.

Specific details of the fauna underpass structures and canopy rope overpasses proposed are illustrated in **Figure 7-1-6**.

■ **Table 7-1-11 Underpass structures proposed for fauna passage**

Chainage	Structure <sup>1</sup>	Fauna mitigation measure	Comments	Link with current Pacific Highway structure
4300	1.2 m high x 2.4 m wide box culvert. Higher invert than 4415 to allow dry passage during wet periods although would still have drainage capabilities during flooding events.	Dedicated fauna passage (FD). Located immediately south of Glenugie Creek and combined with fauna fencing to target both drier forest and riparian passage during most wet and dry periods. Fauna fencing to be installed in the order of 500 m south along both north and south bound carriages.	Threatened fauna targeted Rufous Bettong and Brush-tailed Phascogale, Bush Stone-Curlew. Approximate location to be refined in detailed design. This is the most southern point of the project at which there is connectivity with existing structures on the Pacific Highway and hence opportunity for fauna crossing.	Dedicated 1.5 m pipe for fauna passage combined with fencing. A larger box culvert is not possible at this location as cannot have a blockage on the Pacific Highway for long periods and there is limited relief.
4415	2 x 2.4 m high x 2.4 m wide box culverts with a ledge (0.6 m wide and 0.12 m high) in one culvert to allow passage for during wet periods.	Incidental fauna passage (FI). Underpass structure associated with Glenugie Creek. Combined with fauna exclusion fencing up to 500 m south and 4 km north.	Fish passage capability. Threatened fauna targeted Rufous Bettong and Brush-tailed Phascogale.	Linked with existing structure at ch.4460 (2 x 2.4 m high x 2.4 m wide box culverts) via fauna fencing.
4890	2 x $\phi$ 2.4 pipe culvert.	Combined fauna passage (FC) associated with riparian habitat. Fauna exclusion fencing.	Threatened fauna targeted Rufous Bettong and Brush-tailed Phascogale.	Linked with existing 1500 mm pipe at 4915 m which has some fauna passage capability in dry periods.
5225*	2 x 2.4 m high x 2.4 m wide box culverts.	Combined fauna (FC) Underpass structure associated with creek. Proposed addition of a raised outer dry cell to allow dry passage. Used in combination with fauna exclusion fencing.	Fish passage capability. Fauna targeted include Rufous Bettong and Brush-tailed Phascogale. Large box culverts suitable for a range of small and large terrestrial fauna.	Upgrade to 2 x 2.4 high x 2.4 wide box culverts.
5865*	2.4 m high x 2.4 m wide box culvert with lowered central floor and raised sides (bench) to facilitate fauna movements.	Combined fauna (FC) structure with raised benches added for fauna passage. Fauna exclusion fencing.	Fauna targeted, include Rufous Bettong and Brush-tailed Phascogale. Large box culverts suitable for a range of small and large terrestrial fauna.	Upgrade to 2 x 2.4 m high and 2.4 m wide box culverts with lowered central floor and raised sides (bench) to facilitate fauna movements.



Chainage	Structure <sup>1</sup>	Fauna mitigation measure	Comments	Link with current Pacific Highway structure
6465	2 x 2.4 m high x 2.4 m wide box culvert with lowered central floor and raised sides (bench) to facilitate fauna movements.	Combined fauna (FC) structure with raised benches added for fauna passage. Fauna exclusion fencing.	Fauna targeted, include Rufous Bettong and Brush-tailed Phascogale. Large box culverts suitable for a range of small and large terrestrial fauna.	Linked with existing structure at ch.6485 (2.1 m x 2.1m box culvert) via fauna fencing.
7270	3 x $\phi$ 1.050 pipe culvert.	Incidental fauna (FI) structure.	Target small mammals, reptiles and frogs.	Linked with existing structure at ch.7320 (3 x 750 mm pipes) via fauna fencing.
7395	4 x $\phi$ 1.2 pipe culvert with outer pipe raised.	Dedicated fauna (FD) structure raised to provide dry passage for small fauna during wet periods.	Target small mammals, reptiles and frogs.	Linked with existing structure at ch.7420 (3 x 900mm pipes) via fauna fencing.
7680	3 x $\phi$ 1.2 pipe culvert. Install 0.1 m lip upstream of one cell to make one cell dry.	Incidental fauna (FI) structure.	Target small mammals, reptiles and frogs.	Linked with existing structure at ch.7690 (2 x 1.2 m culverts) via fauna fencing.
10040	4 x $\phi$ 1.2 pipe culvert (on ramp).	Incidental fauna (FI) structure associated with Nine Mile Creek riparian habitat.	Target Rufous Bettong. Suitable for a range of small to medium sized fauna.	Linked with existing structure at ch.9895 (2 x 2.1 m high x 2.1m wide box culverts) via fauna fencing.
10050	1 x $\phi$ 1.2 pipe culvert located off creek for dry passage.	Dedicated fauna (FD) structure positioned for dry passage during wet periods.	Target Rufous Bettong and Bush Stone-Curlew. Suitable for a range of small to medium sized fauna.	Linked with existing structure at ch.9895 (2 x 2.1 m high x 2.1m wide box culverts) via fauna fencing.

1. Details of fauna crossings are indicative only. Details including culvert size, location and cost effectiveness will be finalised in the detailed design phase of the project in consultation with the DECC and DPI. The structures would be incorporated into the project for both the full motorway upgrade and likely initial staging.

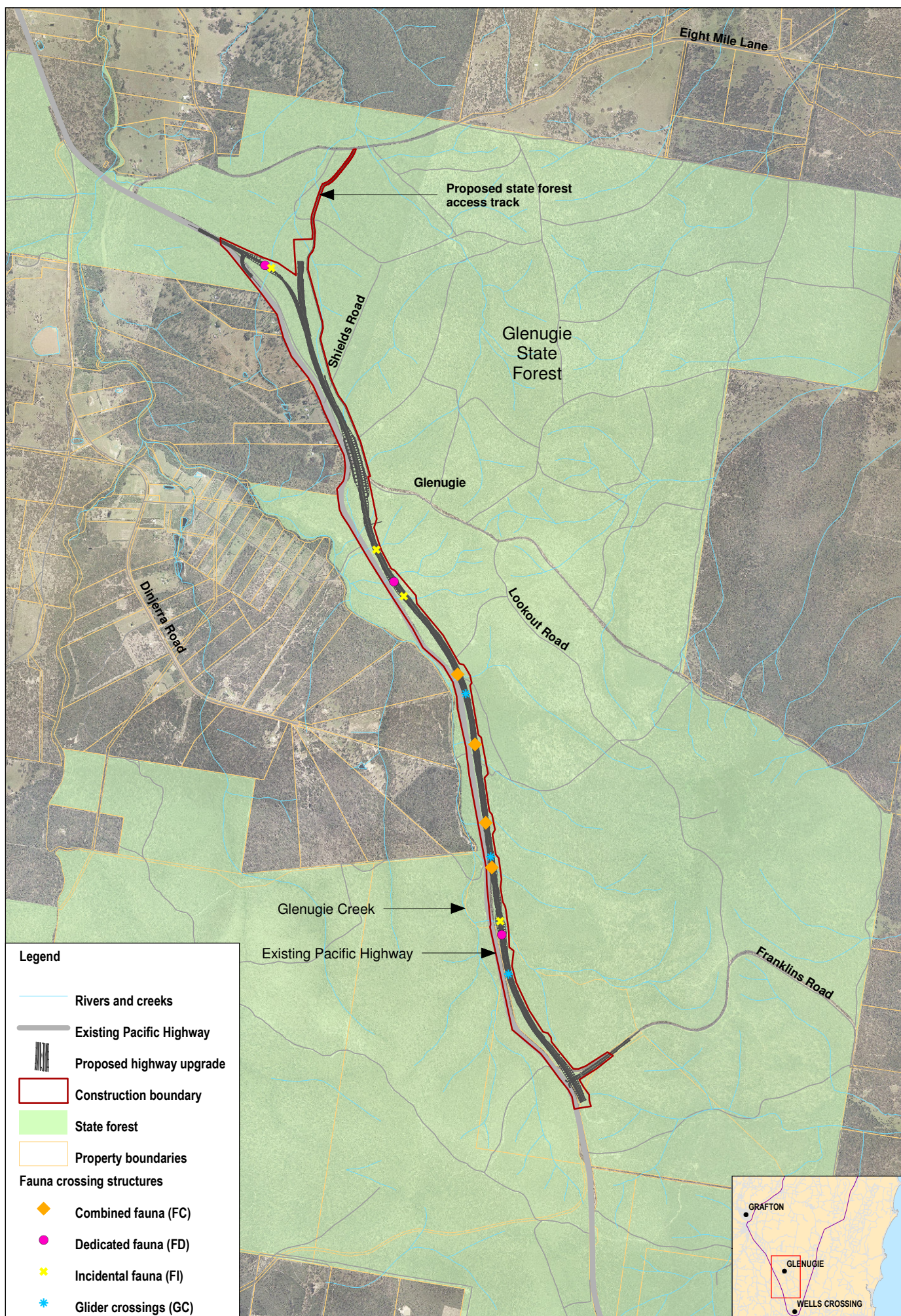
\* Subject to hydraulic requirements to be determined at detailed design stage. Suitability for fauna movement to be determined in consultation with DECC.

■ **Table 7-1-12 Canopy rope structures proposed for fauna passage**

Chainage	Design for likely initial staging	Design for full motorway style upgrade	Existing Pacific Highway	Comments
4000	Canopy rope crossing over the south bound carriageway linked to Glenugie Creek riparian habitat.	Canopy rope crossing extended over the north bound carriageway linked to Glenugie Creek riparian habitat.	-	Dedicated crossing for arboreal mammals, particularly Yellow-bellied Glider and Sugar Glider to maintain connectivity with preferred habitat east and west of the highway, particularly Glenugie Creek riparian habitat.
4900	Canopy rope crossing over the south bound carriageway linked to Glenugie Creek riparian habitat.	Canopy rope crossing extended over the north bound carriageway linked to Glenugie Creek riparian habitat.	Extend canopy rope structure over the existing highway at this location	Crossing for arboreal mammals, particularly Yellow-bellied Glider and Sugar Glider
6300	Canopy rope crossing over the south bound carriageway linked to Glenugie Creek riparian habitat.	Canopy rope crossing extended over the north bound carriageway linked to Glenugie Creek riparian habitat.	-	Crossing for arboreal mammals, particularly Yellow-bellied Glider and Sugar Glider

1. Details of fauna crossings are indicative only. Details including culvert size, location and cost effectiveness will be finalised in the detailed design phase of the project in consultation with the DECC and DPI.





Fauna crossing structures to be confirmed at detail design  
 Data Sources  
 Topodata: Streetworks, LPI 2008  
 Aerial: 2007

**Figure 7-1-6: Fauna crossing structures**



0 1  
 A4 1:40,000 Kilometres



The types and locations of the proposed fauna crossing structures have been selected in consideration of potential fauna movement corridors for specific fauna species (**Table 7-1-13**). The approach is focused on providing dedicated fauna underpasses for species of high conservation value (i.e. Spotted-tailed Quoll, Brush-tailed Phascogale and Rufous Bettong) in addition to overpass structures for the Yellow-bellied Glider in addition to a range of common fauna. Long-term monitoring of fauna underpass structures has shown success for a range of small to medium sized fauna in eastern Australia (eg Goosem 1997; 2001, AMBS 2001, 2002a, 2002b; Taylor and Goldingay 2003). This includes ground-dwelling mammals as large as Red-necked Wallaby and Swamp Wallaby, reptiles and some arboreal mammals such as the koala which have been reported using box culverts (2.4 x 1.2 m and 3 x 3 m) (AMBS 2001, 2002a, 2002b).

With all terrestrial fauna, security from predators is important. Therefore, it is necessary to provide a clear line of sight to light and vegetation at both ends of the crossing. For smaller species, provision of protective cover and structures such as ledges or horizontal logs that are designed to restrict access by larger predators would aid their security. Approaches to the structure should allow good visibility and not be obscured by dense vegetation.

Large fauna require exclusion fencing for guidance through the crossing structure and to prevent access to the carriageway. Fencing is to be provided in proximity to Glenugie Creek and nine Mile Creek covering 90 per cent of the proposed upgrade at the following locations:

- Chainage 3500 through to 8000, a distance of 4.5 km.
- Chainage 9000 to 1010, a further distance of 2.0 km.

■ **Table 7-1-13 Impact mitigation measures for habitat fragmentation**

Species targeted	Distribution of habitat	Mitigation measures proposed
Arboreal fauna: Yellow-bellied Glider, Sugar Glider, Brushtail Possum, Feathertail Glider, Ringtail Possum, Brush- tailed Phascogale (scansorial)	Data on distribution and abundance determined from field survey and data review in conjunction with tree hollow counts. Arboreal mammals were recorded in a wide range of habitats. The highest density of animals was reported in riparian areas and is directly correlated with the greater density of tree hollows.  Open Forest habitats comprising Grey Box, Grey Gum, Bloodwood and Orange Gum are preferred by gliders for feeding, while proximity to riparian areas is also important for denning, shelter and refuge.	Three canopy rope structures placed at strategic locations aimed at providing connectivity to riparian vegetation associated with Glenugie Creek and also high quality feeding and sheltering habitats east and west of the route as identified from the habitat assessment and mapping over the project area. An additional structure also to be-fitted over the existing Pacific Highway. Final locations to be discussed with DECC and DPI Forests.



Species targeted	Distribution of habitat	Mitigation measures proposed
Terrestrial fauna: Small ground-dwelling fauna, Rufous Bettong, Brush-tailed Phascogale (scansorial), Red-necked Wallaby, Swamp Wallaby, Echidna, Bush Stone-curlew, Spotted-tailed Quoll	Data on distribution and abundance determined from field survey and data review. Terrestrial mammals were recorded in a wide range of habitats including open forest and riparian areas. The highest density of Rufous Bettong occurs in the northern end of Glenugie State Forest and particularly associated with riparian areas near Pheasants Creek and Nine Mile Creek.	Three dedicated fauna underpass structures, Four combined fauna structures and Four incidental fauna underpass structures This includes a combination of dedicated, combined and incidental structures designed to provide connectivity with Glenugie Creek and Nine Mile Creek targeting Rufous Bettong, Brush-tailed Phascogale and Bush Stone-curlew.

### Management of riparian and aquatic habitats

Impacts on aquatic and riparian communities would be mitigated through the implementation of specific project design attributes aimed at minimising impacts on hydrological regimes. Specific impact mitigation measures include:

- Changes to existing surface and ground water levels would be minimised through appropriate placement and design of culverts and providing adequate drainage to reflect existing conditions.
- The depth of cuttings in gully areas would be minimised where possible to areas above the natural water table.
- Erosion and sedimentation controls would be implemented.
- Ensuring appropriate design of water storage areas and temporary drainage systems.
- Minimising disturbance and controlling run-off from construction areas.
- Ensuring good maintenance of vehicles to minimise pollution of water from hydrocarbons.
- Response plans to deal with any spillages or accidents that occur at refuelling sites and machinery compounds, which should be part of the CEMP.

The above-listed measures would be integrated with the additional impact mitigation and management measures identified in Section 7.2.3 for channel structure- receiving environments

The installation and operation of structures such as culverts and other instream structures is listed under the FM Act as a key threatening process. Culverts and causeways can modify the natural flow of rivers by increasing, decreasing or altering the seasonality, frequency, magnitude and timing of the flow. Alteration of natural flow regimes can disrupt natural reproductive cues, natural processes of sediment erosion, transport and deposition which can result in a loss of aquatic habitat for fish and macroinvertebrates (DPI 2005). Additionally, culverts can act as a physical barrier to native fish and macroinvertebrate movement and migration by breaking the continuity of water in a stream if its outflow is lifted above the water level downstream of

the culvert. Disruption of movement and migration can result in the disruption of genetic stock. The construction of bridges is excluded as a key threatening process as they have minimal impact upon flow. The addition of culverts to the project have been designed to avoid disrupting fish passage.

### **Management of sedimentation and erosion**

A key threatening process under the FM Act is 'increased sedimentation and erosion during construction of the project'. Increased suspended solids in waterways can impact fish and macroinvertebrate abundance and diversity through clogging of gill structures and benthic smothering (ANZECC/ARCANZ 2000). Increased sedimentation in the rivers due to construction and general operation of the highway can impact on aquatic habitats through increased turbidity. Consequently, this can reduce light penetration in the water column, limit plant growth, and influence predator foraging behaviour. Additionally, increased sediments can fill the interstitial spaces in the substrate, the preferred habitat of a number of macroinvertebrates (ANZECC/ARCANZ 2000). The project will incorporate erosion and sediment controls in accordance with the Blue Books (Landcom 2004).

### **Management of instream woody debris**

Instream woody debris (snags) such as fallen tree trunks, branches and shrubs provide crucial habitat for aquatic organisms including juvenile fish species and macroinvertebrates and provides much of the aquatic habitat at each study site. The potential removal or 'de-snagging' of large tree trunks and branches during construction at water way crossings can remove substrates and periphyton upon which macroinvertebrates feed, as well as the habitat and cover for many macroinvertebrate and fish species.

The NSW DPI Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (1999) states that large woody debris should be retained to the greatest extent possible, however, if during construction of the project the removal of large woody debris is required, lopping/ trimming of the snag should be considered if feasible. If not possible, it is recommended that the woody debris be relocated within the river channel. Permanent removal of large woody debris should be considered as a last resort.

### **Management of pests and diseases**

To minimise the potential for various pests and diseases to be introduced to the study area all construction equipment needs to be washed down prior to arriving on site and preferably before despatch from another project. Washing procedures need to ensure that insect pest and their eggs/larvae are not present on equipment such as red imported Fire Ants, Large Earth Bumblebee, Feral Honeybees, Yellow Crazy Ant and Cane Toads. Diseases also need to be removed from equipment including *Phytophthora cinnamomi*, amphibian chytrid fungus, and beak and feather disease. Equipment should be washed of any sediments and debris and disinfected.

### **Management of key threatening processes**

Key threatening processes are listed in **Table 7-1-8** along with reference to proposed mitigation measures. The key threatening processes that have the highest level of threat as a result of the project are those regarding weed

invasion, altered hydrology and native vegetation clearing and removal of key fauna habitats such as hollow-bearing trees.

### **Management of regional scale cumulative impacts**

The cumulative impacts of the project would be minimised where possible through retaining and protecting areas of native vegetation. Other mitigation measures mentioned in this section would contribute to minimising cumulative impacts on vegetation (including threatened species) and wildlife corridors.

### **Monitoring**

An appropriate monitoring strategy is to be prepared as part of the FFMP. The strategy is to outline methods and timing for monitoring key threatened species impacted by the project. The following issues are relevant to the strategy:

- Monitoring of rehabilitation areas should be conducted twice annually during construction and for at least two years post construction. Based on the results of this monitoring it would be decided if further monitoring is necessary.
- Monitoring of *Melaleuca irbyana* plantings should be conducted monthly for the first six months during construction. Once plants are established, the monitoring frequency could be adjusted to twice annually for up to two years post construction.
- Yellow-bellied gliders should be monitored during the construction and for at least two years post construction. Issues to be addressed include presence in areas adjacent to the construction corridor and the use of the canopy rope structures. The latter is particularly important as this species is not currently being monitored as part of existing programs for the Pacific Highway and the data may assist the future the proposed Wells Crossing to Iluka Road upgrade.
- A monitoring program for fauna underpasses is to be conducted with a focus on the Rufous Bettong. While several such programs have been conducted to date for highway underpasses, none have focused on the Rufous Bettong. The data to be collected would include surveys for presence adjacent to underpass structures and the use of such structures. This would provide valuable data for future sections of the Wells Crossing to Iluka Road upgrade.

### **Biodiversity offsetting**

There would be some remaining impacts on biodiversity that cannot be adequately mitigated for the project such as:

- A loss of native vegetation including vegetation which comprises the nationally threatened square-fruited ironbark (*Eucalyptus tetrapleura*).
- A loss of habitat for native flora and fauna including the threatened species *Melaleuca irbyana*, threatened mammals and birds.

These residual impacts would be ameliorated through the development of a biodiversity offset strategy that aims to maintain or improve biodiversity values in the project area in the long-term. The strategy would be developed in consultation with DEWHA, DECC and the Department of Planning.