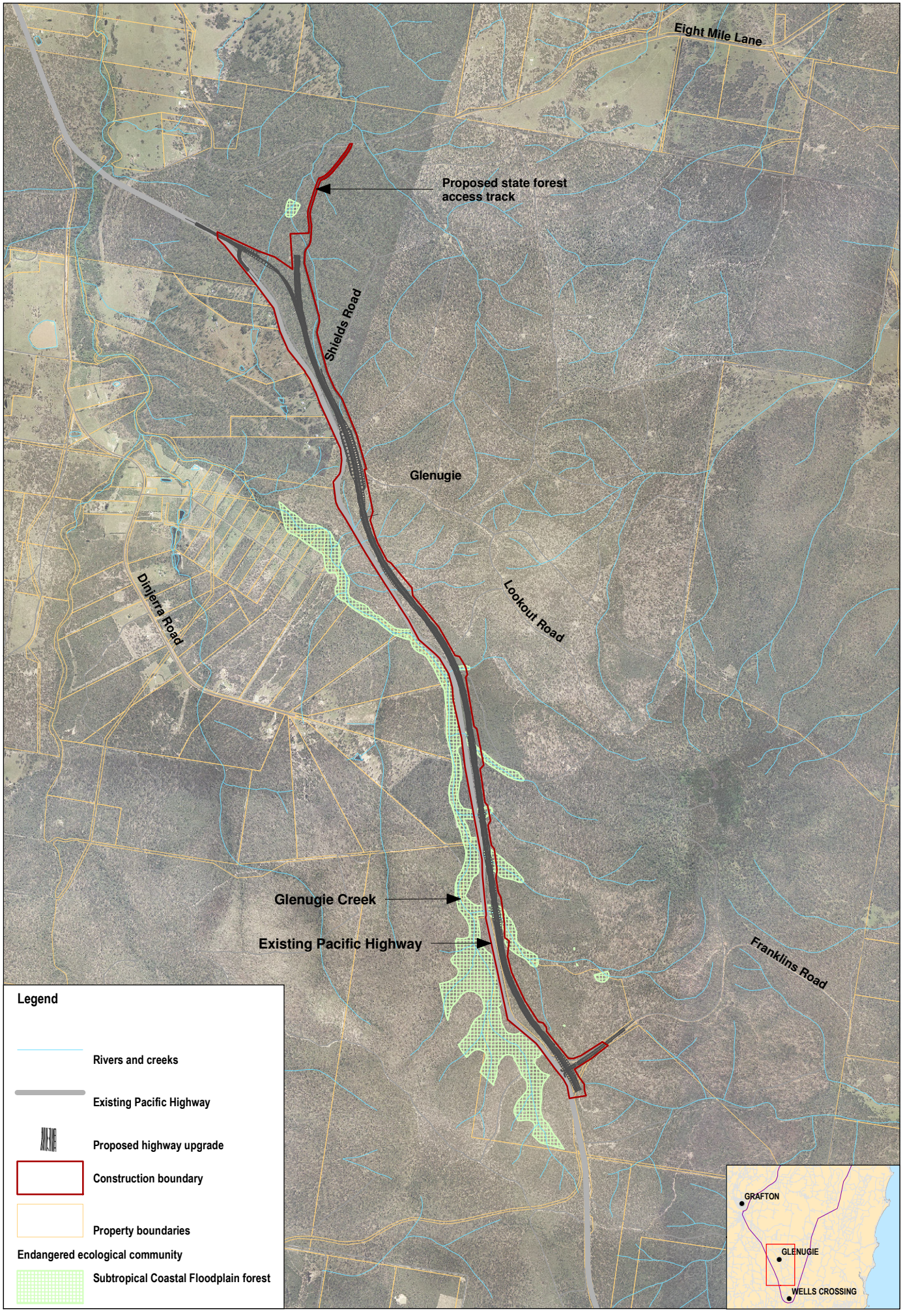


Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007

Figure 4-1: Endangered ecological communities

0 1
A4 1:40,000 Kilometres

4.3. Threatened flora

Threatened flora species identified in the preferred route corridor are listed in **Table 4-2**, along with their conservation status, distribution and abundance. Threatened flora species that are cryptic in growth habits and considered to potentially occur in the study area based on known preferred habitat conditions and local records are discussed in Section 4.3.3.

- **Table 4-2 Threatened flora located within the study area**

Species	Conservation status			Distribution and abundance
	Cwlth	NSW	RoTAP	
Square-fruited Ironbark (*Eucalyptus tetrapleura)*	V	V	2VCa	A large population of *Eucalyptus tetrapleura* is present within and surrounding the project footprint. The local population occurs as larger contiguous populations and several smaller isolated sub-populations within an about 6 km radius of the project footprint. The local population is estimated to support 147,000 individuals and the entire population is estimated to be 170,000 and 250,000 individuals. There are estimated to be about 6156 individuals within the project footprint (i.e. <5 % of the entire population).
Weeping Paperbark (*Melaleuca irbyana)*	-	E	-	About 31 individuals were identified within the central area of the project footprint. Another sub-population supporting about 114 individuals is present about 2.5 km to the northeast also in Glenugie State Forest. There are likely to be other occurrences of this species in the surrounding areas of habitat not surveyed. The project would result in the direct removal of 5-10 individuals, and the remaining 21-26 individuals would be potentially threatened by associated habitat modification and other indirect impacts associated with the project.

V= vulnerable E= endangered RoTAP= rare or threatened Australian plant

2VCa= geographic range < 100km, vulnerable, reserved with 1000 plants or more known to occur within the conservation reserve.

4.3.1. Eucalyptus tetrapleura

Description

Eucalyptus tetrapleura is a medium-sized tree growing up to 30 m tall with a relatively straight trunk and deeply furrowed dark brown or black 'ironbark' which extends to the small branches. The bark is similar to other ironbark species occurring in the same area, particularly Broad-leaved Ironbark (*Eucalyptus fibrosa*), as they both have a flakier bark than the typically hard bark of the grey ironbarks.

Adult leaves are up to 20 cm long, curved and dull green on both sides. The four-angled buds have distinctively small caps that protrude at the end. The conical or pear-shaped fruits are quadrangular in cross-section.

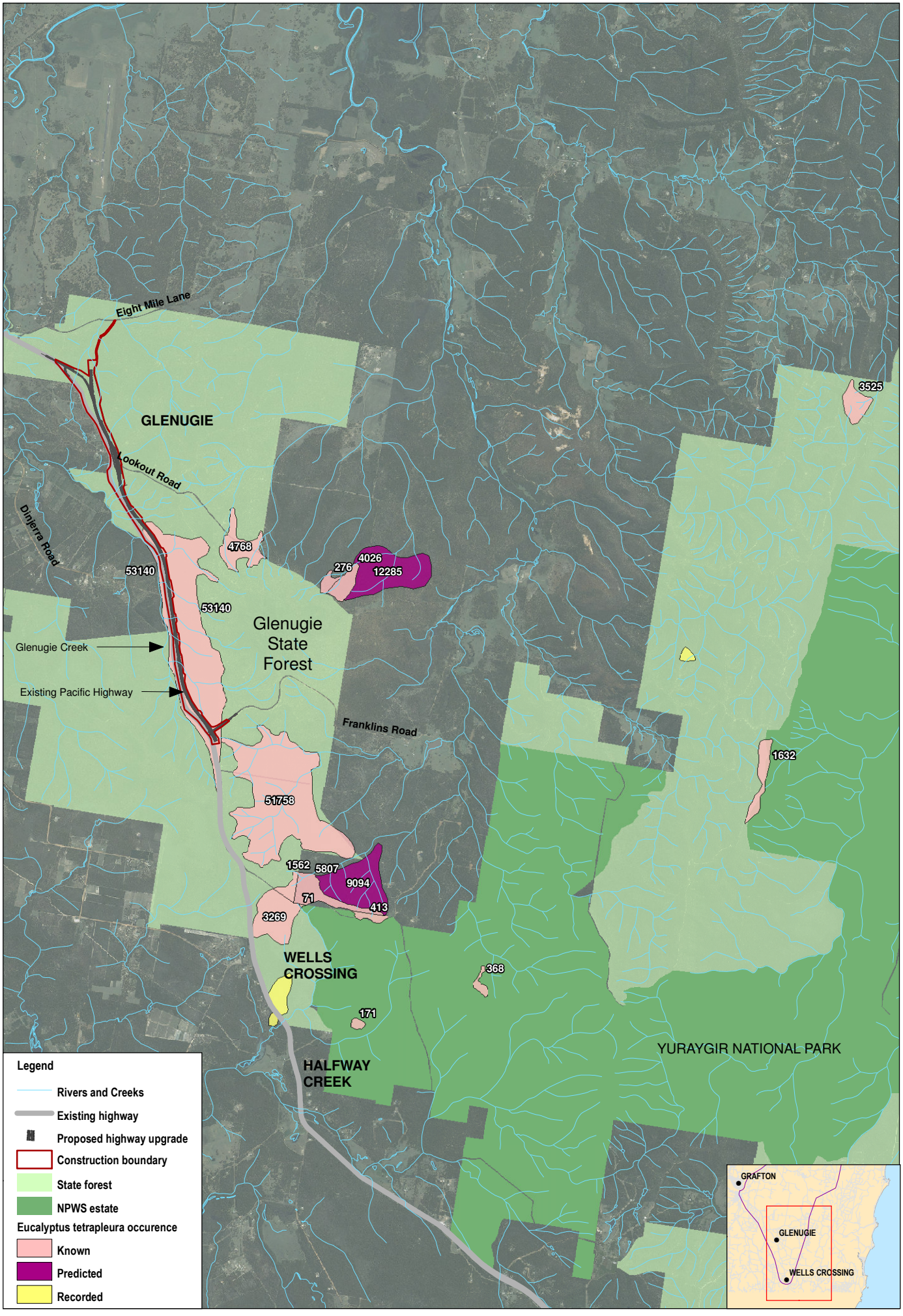
The fruits and buds are very distinctive and distinguish this species from other ironbark species occurring within its natural range. The leaves are also diagnostic of the species being a dull grey green and having a drooping appearance which can be used to distinguish it from other ironbark species from a distance.

Distribution and habitat

Eucalyptus tetrapleura is endemic to coastal lowlands and foothills from near Glenreagh in the south to Casino in the north, occurring within a range of about 100 km north to south, and 50 km east to west. Within this range, the current known distribution is patchy, however the species has not been extensively surveyed and the full extent of the population is unknown. The known local and regional distribution *Eucalyptus tetrapleura* is shown in **Figure 4-2**, **Figure 4-3**, **Figure 4-4** and **Figure 4-5**.

Habitat for *Eucalyptus tetrapleura* is not well defined and is not restricted to one particular vegetation association, landform, soil type or geology. Its occurrence was observed to be more associated with a number of physical features influencing soil moisture and groundwater levels, including soil texture, soil depth, slope, bedrock geology, subsoil permeability. In several areas soil texture was observed to be a limiting factor to the distribution of *Eucalyptus tetrapleura*, occurring on more sandy soils overlaying a clayey subsoil, with *Eucalyptus fibrosa* becoming dominant in areas where the soil becomes more clayey. In other areas groundwater drainage appeared to be a major influence with *Eucalyptus tetrapleura* occurring on areas of relatively shallow soils overlying a sandstone bedrock such as in Chambigne Nature Reserve and Yuraygir State Conservation Area. Overall *Eucalyptus tetrapleura* seems to occupy a niche where it is able to out-compete other Eucalypt species where soils are not too dry or wet, where drainage is not significantly impeded and in some circumstances where soils are not too shallow but shallow enough for the bedrock to influence groundwater levels.

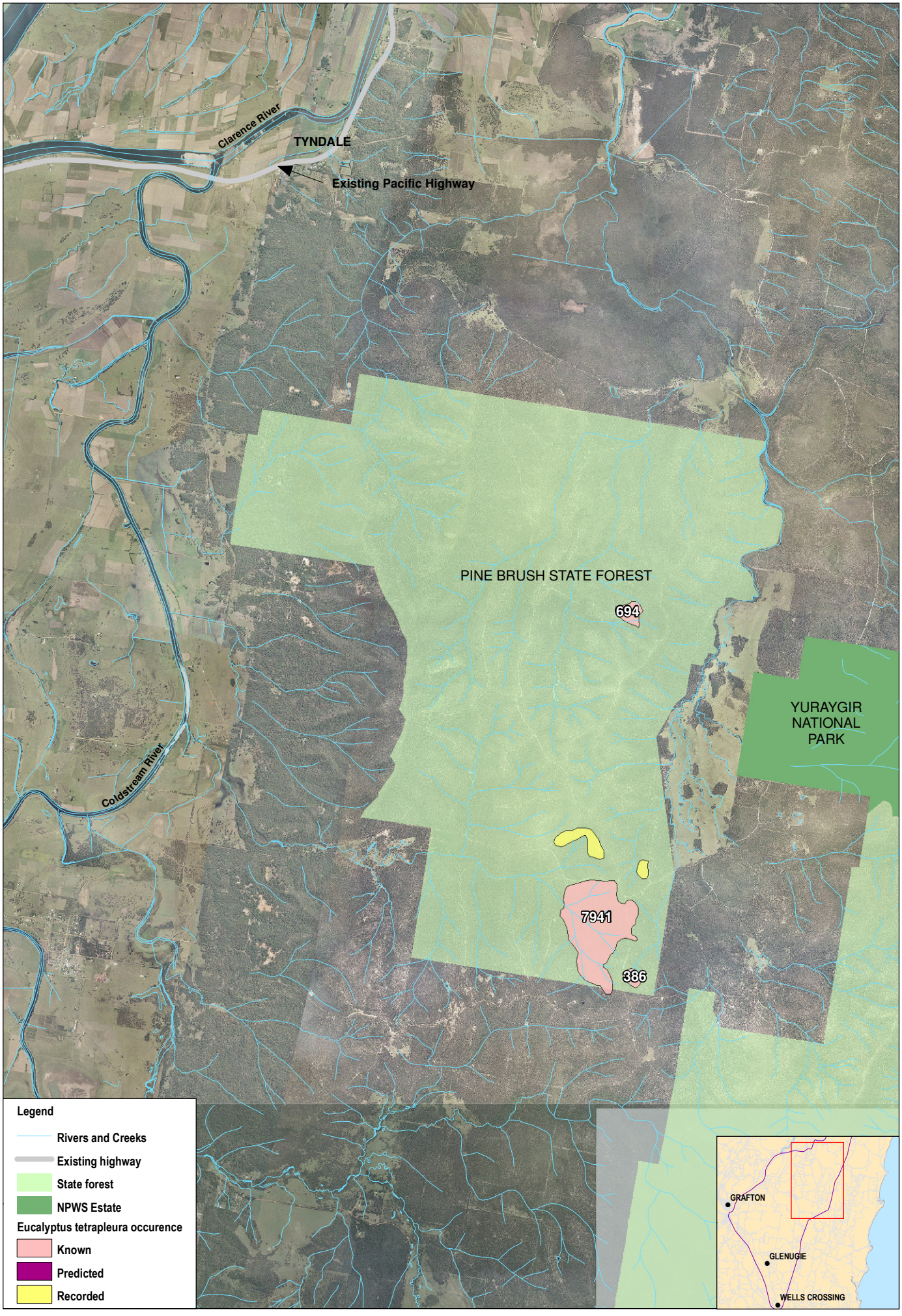
In Glenugie and Pine Brush State Forests *Eucalyptus tetrapleura* was recorded in two broad vegetation associations and occurs in all topographic situations including ridges, gullies and upper, lower and mid slope areas (refer to **Figure 4-2** and **Figure 4-3**). *Eucalyptus tetrapleura* is mainly associated with Large-leaved Spotted Gum (*Corymbia henryi*) on ridges and slopes. It also occurs in broad depressions, gullies and riparian areas with a wide range of species, particularly Narrow-leaved Red Gum (*Eucalyptus seeana*). Species recorded during the study occurring with *Eucalyptus tetrapleura* include Forest Red Gum (*Eucalyptus tereticornis*), Grey Box (*Eucalyptus moluccana*), Pink Bloodwood (*Corymbia intermedia*), Red Mahogany (*Eucalyptus resinifera*), Swamp Turpentine (*Lophostemon sauveolens*), *Angophora woodsiana*, Small-fruited Grey Gum (*Eucalyptus propinqua*), Orange Gum (*Eucalyptus bancroftii*), White Mahogany (*Eucalyptus acmenoides*) and Paperbarks (*Melaleuca* spp.). In many areas *Eucalyptus tetrapleura* is associated with a thick shrub understorey including Ball Honey-myrtle (*Melaleuca nodosa*), Black She-oak (*Allocasuarina littoralis*) and Curracabah (*Acacia concurrens*).



Data Sources
Topodata: Streetworks, LPI 2008
Aerial: SPOT Maps, 2007

Figure 4-2: Distribution of *Eucalyptus tetrapleura* in the study area

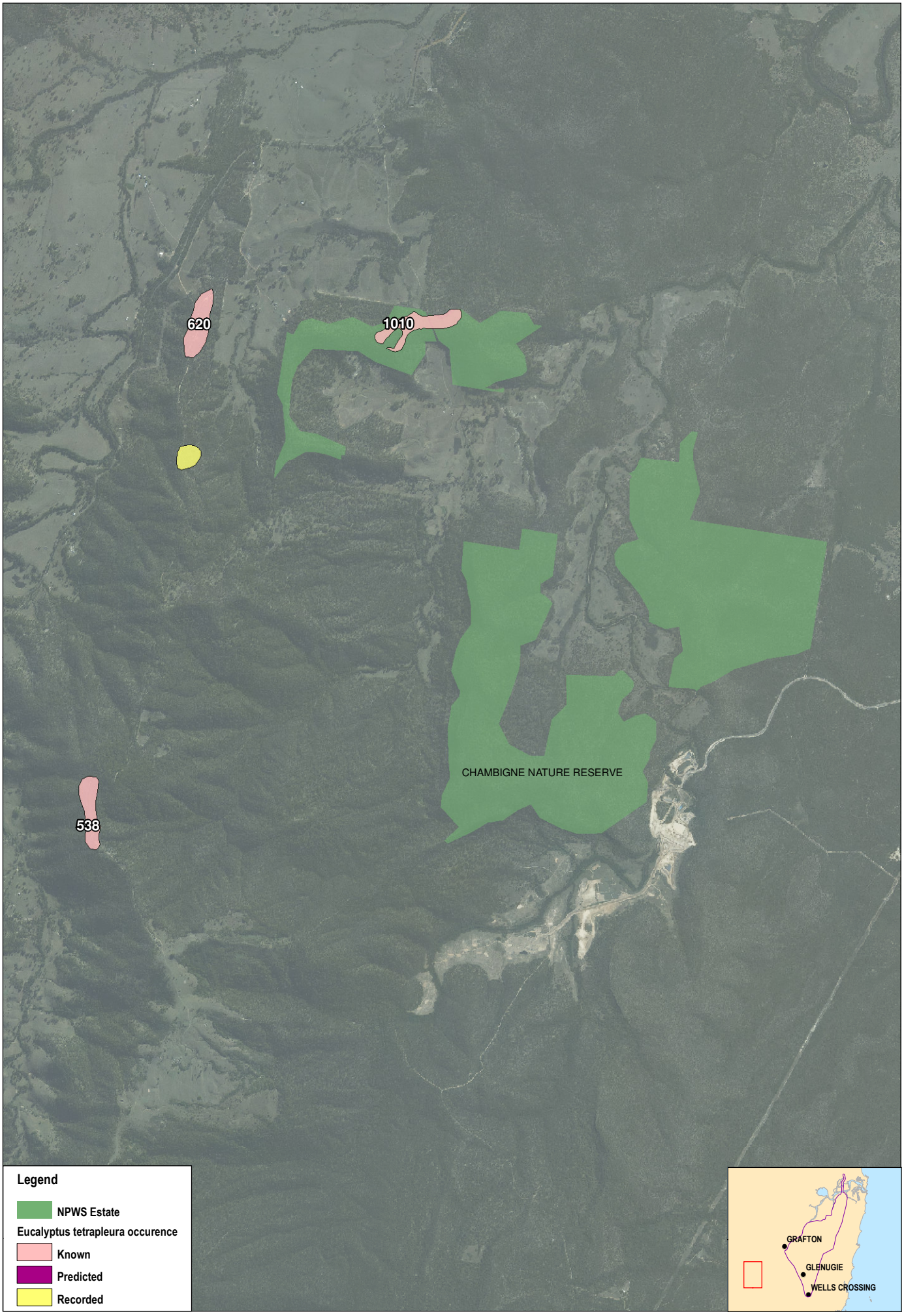
0 2
A4 1:90,000 Kilometres



Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007, SPOT Maps, 2007

Figure 4-3: Regional distribution of *Eucalyptus tetrapleura* in Pine Brush State Forest

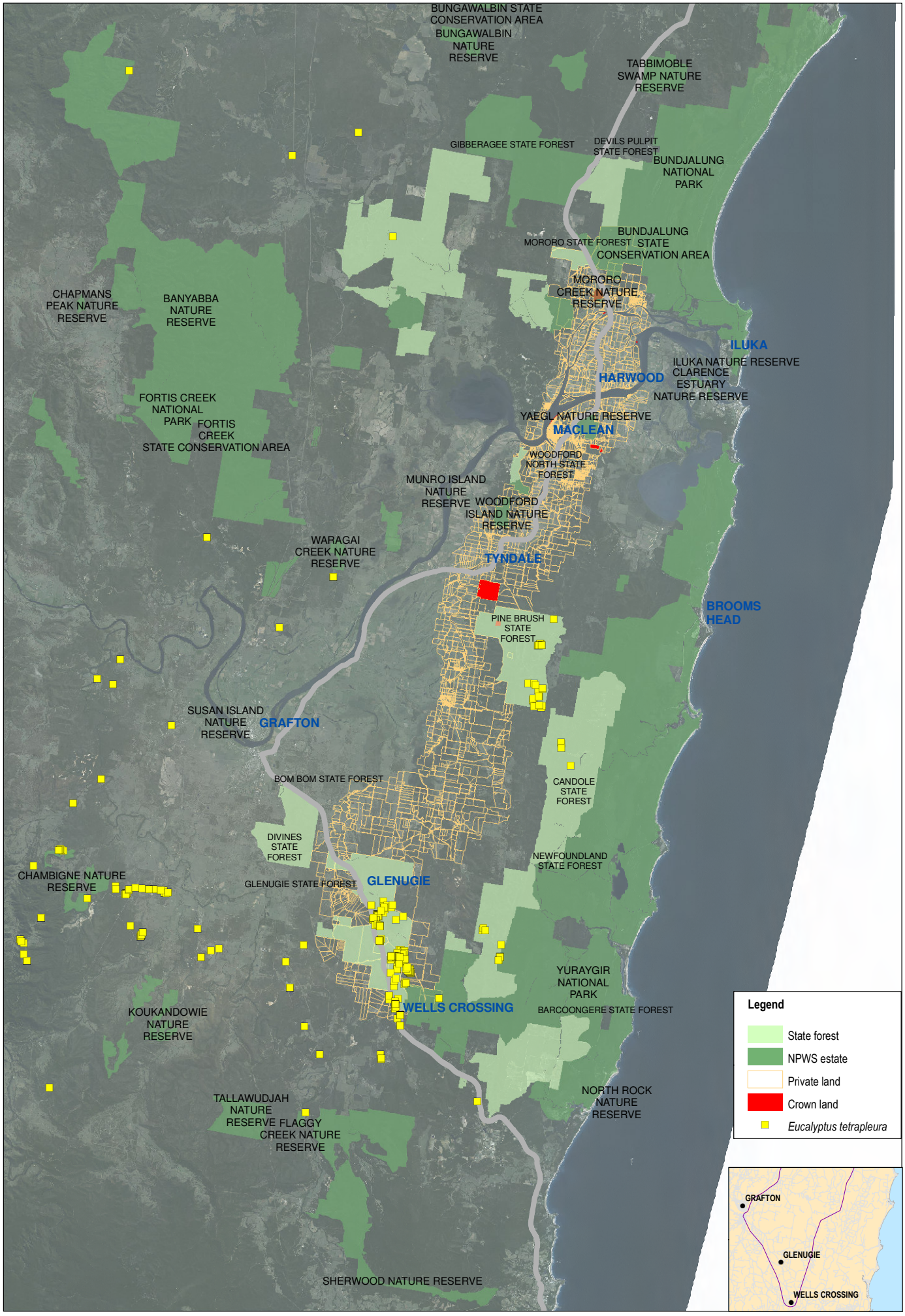
0 2
A4 1:70,000 Kilometres



Data Sources
Topodata: Streetworks, LPI 2008
Image: SPOT Maps, 2007

Figure 4-4: Regional distribution of *Eucalyptus tetrapleura* - Chambigne Nature Reserve

0 2
A4 1:50,000 Kilometres



Data Sources
Flora data: DECC 2009
Topodata: Streetworks, LPI 2008
Image: SPOT Maps, 2007

Figure 4-5: Total regional distribution of *Eucalyptus tetrapleura*

0 10
A4 1:420,000 Kilometres

In Chambigne Nature Reserve (refer to **Figure 4-4**) *Eucalyptus tetrapleura* occurs towards the top of the sandstone escarpment on gentle sloping benches between the rocky outcrops on top of the escarpment and the cliff areas or steeper slopes surrounding the escarpment. In this area *Eucalyptus tetrapleura* forms a dominant component of the vegetation community particularly on the western facing side of the escarpment. Associated species in Chambigne Nature Reserve include Bailey's Stringybark (*Eucalyptus baileyana*), Large-fruited Blackbutt (*Eucalyptus pyrocarpa*), Red Bloodwood (*Corymbia gummifera*), Bastard Tallow-wood (*Eucalyptus planchoniana*), Bastard White Mahogany (*Eucalyptus psammitica*) and the threatened species Sandstone Rough-barked Apple (*Angophora robur*).

Within areas of Yuraygir Crown Reserve *Eucalyptus tetrapleura* was recorded in areas supporting Tallowwood (*Eucalyptus microcorys*), Scribbly Gum (*Eucalyptus sclerophylla*) and Stringybark (*Eucalyptus tindaliae*). These areas have sandy soils and *Eucalyptus tetrapleura* occurs in low to moderate abundances in these areas.

Although *Eucalyptus tetrapleura* does occur with other ironbark species in a few areas, it usually is the dominant ironbark species where it occurs, and other ironbark species are generally limited to the edges of its preferred habitat conditions. Other ironbark species occurring with *Eucalyptus tetrapleura* recorded during the surveys include Broad-leaved Ironbark (*Eucalyptus fibrosa*), Northern Grey Ironbark (*Eucalyptus siderophloia*), Thin-leaved Ironbark (*Eucalyptus crebra*) and Grey Ironbark (*Eucalyptus fusiformis*).

Regional distribution

The total regional distribution of *Eucalyptus tetrapleura* is shown in **Figure 4-5**. The major populations for *Eucalyptus tetrapleura* were recorded in the Glenugie area including the population within the study area. Populations are predicted to be present to the east of Glenugie State Forest on private property adjoining Yuraygir State Conservation Area and Glenugie Peak Flora Reserve (refer to **Figure 4-2**). At the western extent of the distribution of *Eucalyptus tetrapleura*, it was recorded along areas of Rockview Road about 30 km west of the study area and was observed to extend into areas of private property surrounding this road. Although no population assessments were carried out, *Eucalyptus tetrapleura* is expected to be relatively abundant in this area based on field observations and species records.

The local abundance of the species varied considerably within each of the different populations and so separate densities were calculated for each population. The density of trees was often dependant on the degree of recruitment, with some areas supporting a large number of juvenile trees and smaller saplings, whilst other areas supported more mature trees with fewer juveniles. The abundance of juveniles is dependent on several factors including fire history, understorey structure and other disturbances such as logging activities. Many of the state forest areas supported a large number of juveniles possibly due to past disturbance from logging activities providing bare soil for germination. However certain fire regimes are likely to favour

recruitment, such as a fire during the major fruiting period for *Eucalyptus tetrapleura*, providing bare surface substrates for germination of plant-stored seed.

Population estimates were undertaken for several locations in the region including State Forests and National Park estates. The population estimates for each of the areas assessed are detailed in **Table 4-3**.

- **Table 4-3 Estimated individuals occurring within each assessment area**

Location	Occurrence	Area of population (ha)	Population estimate
Glenugie State Forest	Assessed	664.35	109,656
Pine Brush State Forest	Assessed	139.31	10,336
New Foundland State Forest	Assessed	53.51	5511
TOTAL - State Forest		**857.17**	**125,503**
Chambigne Nature Reserve	Assessed	13.28	1010
Yuraygir State Conservation Area	Assessed	18.7	1023
Wells Crossing Flora Reserve	Assessed	79.35	4444
TOTAL - Conservation Reserves		**111.33**	**6477**
Private property – Glenugie	Predicted	247.89	31,680
Private property – Rockview	Confirmed Records	28.18	1409
TOTAL - Private Property		276.07	33,089
Shannon Creek Dam	Confirmed	170	3173
TOTAL – Crown Land			3173
TOTAL ESTIMATED		**1,244.57**	**168,242**

The data presented above provide a population estimate for nine sites. However the total population number is estimated to be significantly larger than indicated in **Table 4-3** as many additional records (DECC Atlas of NSW Wildlife) occur on private lands to the west of Glenugie State Forest (i.e. at least 30 records) that have not been assessed in detail (refer to **Figure 4-2**). Additionally the species is also known to occur in the vicinity of the following locations:

- Whiporie State Forest.
- Gibberagee State Forest.
- Candole State Forest.
- Southgate State Forest.
- Camira State Forest.
- Fullers State Forest.
- Mt Neville Nature Reserve.
- Sherwood Nature Reserve.
- Ramorning National Park.

The total regional population based on recorded locations to date is therefore considered to comprise in the order of 50 different sub-groups with a conservative estimate of between 170,000 and 250,000 individuals.

The Glenugie population is considered to cover a six kilometre radius of the study area and is estimated to consist of about 147,000 trees, made of the following groups:

- Glenugie State Forest – 109,656.
- Wells Crossing Flora Reserve – 4,444.
- Yuraygir State Conservation Area – 1,023.
- Private property Glenugie 31,680 - (predicted).

The predicted occurrence of *Eucalyptus tetrapleura* on private property was determined through extrapolating the preferred habitat of this species based on the known distribution of the species in adjacent state forests and conservation reserves. A combination of two metre contour data, and the known landscape position/habitat preference for surrounding populations was used for predicting the presence of *Eucalyptus tetrapleura* on private property. Therefore where populations of *Eucalyptus tetrapleura* on private property are contiguous with populations in state forests and conservation reserves the known landscape position/habitat were extrapolated into private properties. For example, some populations were correlated with lower and mid slopes whilst others were correlated with ridges and upper slopes.

Protection in conservation reserves

A large proportion of the population was recorded within active logging zones of State Forests and private lands, and therefore is not formally protected. The extent of the species within protected areas of some state forests (Special Management Zones) and National Park estates was recorded within several protected areas. The total area assessed supporting *Eucalyptus tetrapleura* within conservation reserves comprises about 111 ha which is estimated to support 6477 individuals.

Of the local population (about 147,000 trees) described above about 3-4 per cent of these are present within conservation reserves. The total known reserved extent of the population local in the study area comprises about 5467 individuals occurring in Yuraygir State Conservation Area and Wells Crossing Flora Reserve. Additionally there are likely to be other reserved populations in the study area within Glenugie Peak Flora Reserve and Yuraygir National Park. Outside of the population local to the study area there are about 1010 individuals reserved within one section of Chambigne Nature Reserve. Additionally there are records in the other section of Chambigne Nature Reserve near Shannon Creek Dam.

The conservation reserves assessed included two National Park estates in addition to Wells Crossing Flora Reserve (Management Zone 1). Locations that were easily accessible were

assessed within these conservation reserves however it is possible that there are other locations within these reserves, and it has also been recorded in Yuraygir National Park. Several individuals were found on the edge of Glenugie Peak Flora Reserve which are part of a larger population extending into private land to the east of Glenugie Peak. There is also a record (DECC 2009) towards the top of Glenugie Peak that was not investigated due to lack of access and time constraints.

The main area of Chambigne Nature Reserve north of Shannon Creek Dam could not be accessed during the surveys, however there are records (DECC 2009) occurring in this area. Considering the presence of suitable habitat observed in and surrounding Chambigne Nature Reserve and Yuraygir State Conservation Area, it is considered possible there are other unidentified populations within these reserves and in surrounding areas of private land.

The populations within state forest areas have a certain level of protection from forestry operation under the under the Terms of Licence under the TSC Act. The following must apply to forestry operations within these areas under the Terms of Licence:

"A minimum of 90 per cent of individuals must be protected from specified forestry activities. During harvesting operations, the potential for damage to these plants must be minimised by utilising techniques of directional felling"

Note: Where there are few individuals within the compartment and the individuals are widely dispersed within the compartment, at least 90 per cent of individuals must be protected from specified forestry activities*. Where there are a large number of individuals within the compartment and they occur in groups, the group or groups should be protected. A group is defined as more than one individual located less than 20 metres apart.*

Therefore at least 90 per cent of the individuals estimated to occur in the state forest areas must be protected, comprising an estimated 135,747 individuals. The total estimated number of individuals which should be protected in conservation reserves and operation areas of state forests comprises 141,049 individuals.

Potential impacts

The population of *Eucalyptus tetrapleura* within the project footprint is part of a large contiguous population extending to the south and east over an area of about 613 ha. There are also several populations to the east and south of the project footprint and on the western side of the existing highway which are considered to be part of the local population, in total comprising 147,000 individuals. These 147,000 individuals occurring within about six kilometres 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.

Densities of *Eucalyptus tetrapleura* in the project footprint are relatively high based on transect assessments, with an average density of 171 individuals per hectare. The project footprint includes about 36 ha of the local population which is estimated to include 6156 individuals. This project would remove an estimated 4.2 per cent of the local population and between 2.5 and 3.6 per cent of the total known population of this species.

4.3.2. Melaleuca irbyana

Description

Melaleuca irbyana has thick, spongy, papery bark and grows to about eight metres tall. It has a dense, rounded canopy of very fine, weeping foliage. The tiny, stalkless, pointed leaves are less than four millimetres long, smaller than any other *Melaleuca* species growing in the local area. The leaves are appressed close to the branchlets, wrapping around them slightly. In summer profuse white flowers, arranged in groups of three, are present and are followed by tight clusters of woody fruits.

Distribution and habitat

Melaleuca irbyana is found in only a few places in north-east NSW, including near Coraki, Casino and Coutts Crossing south of Grafton. It also occurs near Ipswich in south-east Queensland. It is generally known from open eucalypt forest in poorly drained, usually clay soils.

Melaleuca irbyana doesn't have a well defined habitat preference within the study area. It appears to be associated with creek line areas and lower-mid zones of gentle slopes surrounding drainage lines. It occurs in relatively low abundance within this area of habitat. The area of suitable known habitat for *Melaleuca irbyana* is estimated to occur over a 17 ha area in close proximity to the project footprint. The potential habitat for the species in Glenugie State Forest includes a very large area, however the sporadic occurrence of the species suggests that its distribution is dependent on a range of different factors.

Surrounding the project footprint in the local area there are several populations of *Melaleuca irbyana* recorded on the DECC Atlas of NSW Wildlife (2009), with at least 166 individuals recorded. One of the main populations indicated in the local records is about 2.5 km north east of the project footprint and comprises 114 individuals on the eastern edge of Glenugie State Forest, occurring about over a six hectare area (refer to **Figure 4-6**). The study area is towards the known southern extent of the species, however there is a record in Glenugie State Forest about five kilometres to the south of the population in the project footprint. Additionally there are also populations about 12 km to the west of the project footprint and to the north in the Pillar Valley area.

Local distribution

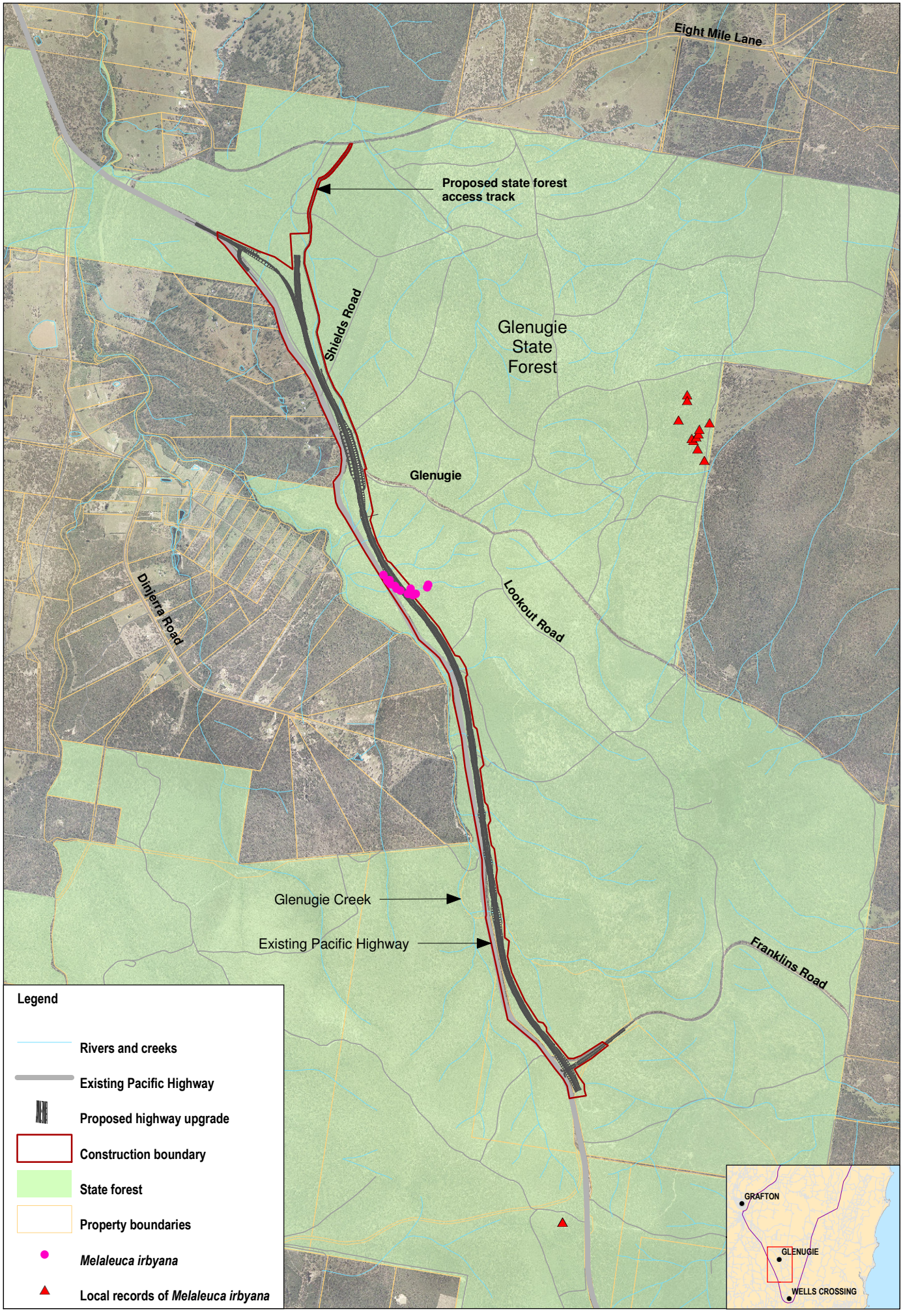
About 31 individuals were identified within the central area of the study area, with some plants (5-10) present within the project footprint. There are likely to be other occurrences of this species in the surrounding areas of habitat, however more targeted investigations would be required to accurately determine the extent of the local population and the total area of habitat occupied by *Melaleuca irbyana* in the local area.

The project would result in the direct removal of 5-10 individuals, and the remaining 21-26 individuals would be potentially threatened by associated habitat modification and other indirect impacts associated with the project, such as altered hydrology, edge effects and weed invasion.

There may be other locations of *Melaleuca irbyana* in Glenugie State Forest that have not been identified between the sub-populations which have not been detected that act as “stepping stones” between the sub-population in the project footprint and sub-populations to the north east (refer to **Figure 4-6**). The local population for *Melaleuca irbyana* could be considered to include both the population within the project footprint and the population 2.5 km to the north east, considering the high mobility of potential pollinator species and wind dispersal of pollen, and the possibility of other individuals being present between these known locations. Therefore the total population size is estimated to be 145 individuals, with the plants potentially impacted from the project comprising between three and seven per cent of the local population. However, 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.

Potential impacts

A small population of *Melaleuca irbyana* was recorded in the study area comprising about 31 individuals of which up to 10 may be impacted from the project however there is potential to retain more individuals adjacent to the project footprint and reduce the impacts to five individuals. The local population for *Melaleuca irbyana* is considered to extend beyond the study area due to the high mobility of potential pollinator species and wind dispersal of pollen. To mitigate potential impacts to loss of genetic diversity from local sub-population a number of mitigation measures are required to maintain some of the genetic diversity such as seed collection and propagation and translocation of individuals which are proposed to be removed.



Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007

Figure 4-6: Location of *Melaleuca irbyana* in the study area

0 1
A4 1:40,000 Kilometres

4.3.3. Regional threatened flora records

There are records for 15 threatened flora species identified within a 10 km radius of the project footprint and an additional 23 threatened flora species identified as potentially occurring from database searches and literature reviews (refer to Appendix A).

While only two of these species were identified in the corridor during intensive surveys, there is potential for additional threatened plant species to occur that have suitable habitat present. These are listed in **Table 4-4**.

Table 4-4 Threatened flora potentially present in the study area

Species	Conservation status			Distribution and abundance
	Cwlth	NSW	RoTAP	
Boronia umbellata Orara Boronia	V	V	2VC-	Found at only a few locations between Glenreagh and Lower Bucca, north of Coffs Harbour, but it is locally common in the restricted area where it occurs. This Boronia grows as an understorey shrub in and around gullies in wet open forest. This species was not identified in the study area despite targeted searches in areas of suitable habitat. It is considered unlikely that this species is present in the study area and no further assessment is required.
Leafless Tongue Orchid *Cryptostylis hunteriana*	V	V	3VC-	The study area supports potential habitat and is within the natural distributional range for this species. It does not have well defined habitat preferences and is known from forests, swamp-heath and woodland. It is often found in association with the Large Tongue Orchid (*Cryptostylis subulata*) and the Tartan Tongue Orchid (*Cryptostylis erecta*), which were not recorded in the study area. Surveys were not undertaken within the flowering period for *Cryptostylis hunteriana*. Although the study area may potentially provide habitat for this species, the habitat attributes 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.
Small Pale Grass-lily *Caesia parviflora var. minor*	-	E	-	Found in damp places in open forest on sandstone. This variety occurs uncommonly in Tasmania, southern Victoria and south-east South Australia with an outlying population in NSW, in Barcoongere State Forest, between Grafton and Coffs Harbour. This variety may be more common than currently known, as Pale Grass-lilies are often not identified to variety level. There is potential habitat for this species in the study area although generally marginal. It is recommended that surveys be undertaken for this species during spring/summer when this species is flowering.
Centranthera cochinchinensis Swamp Foxglove	-	E	-	Occurs in northern Australia and south-east Asia and known from NSW north from Wooli. Uncommon in swampy areas and other moist sites. 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.

Species	Conservation status			Distribution and abundance
	Cwlth	NSW	RoTAP	
Maundia triglochinoides	-	V	-	Restricted to coastal NSW north from Wyong extending into southern Queensland. Grows in swamps, creeks or shallow freshwater 30-60 centimetres deep on heavy clay with low nutrients. Flowering occurs during warmer months and is associated with wetland species such as *Triglochin procerum*. There are suitable areas of habitat along creek lines with water holes with *Triglochin procerum* in the study area. Despite searches being undertaken for *Maundia triglochinoides* in the study area suitable areas of habitat, no individuals were identified, although searches were not undertaken during the optimal flowering period. There are records of this species 9-15 kilometres to east of the project footprint. Considering this species was not identified in the study area during surveys and suitable habitat is restricted to a small area, however it is recommended that surveys be undertaken for this species during spring/summer.
Rutidosis heterogama	V	V	2Vca	Scattered coastal locations between Wyong and Evans Head, and on the New England Tablelands from Torrington and Ashford south to Wandsworth south-west of Glen Innes. Grows in heath on sandy soils and moist areas in open forest, and has been recorded along disturbed roadsides. The study area provides suitable habitat attributes for this species. There are no records of this species in the local area. Surveys were undertaken during the flowering period for this species, however no individuals were recorded. This species appears to be restricted to coastal habitats in the region, with the nearest records present 20 km to the east. It is considered unlikely that this species is present in the study area and no further assessment is required.
Tylophora woollsii Cryptic Forest Twiner	E	E	2E	Found on the NSW north coast and New England Tablelands to southern Queensland, but is very rare within that range. 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 but sometimes as late as November. 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 in the study area, however this species was not found despite targeted searches. 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.

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

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. It has been recommended that additional surveys be undertaken within the study area to target cryptic rare and threatened flora species such as orchids and other cryptic flora that primarily flower during spring and summer. These are listed in **Table 4-4**.

4.4. Threatened fauna

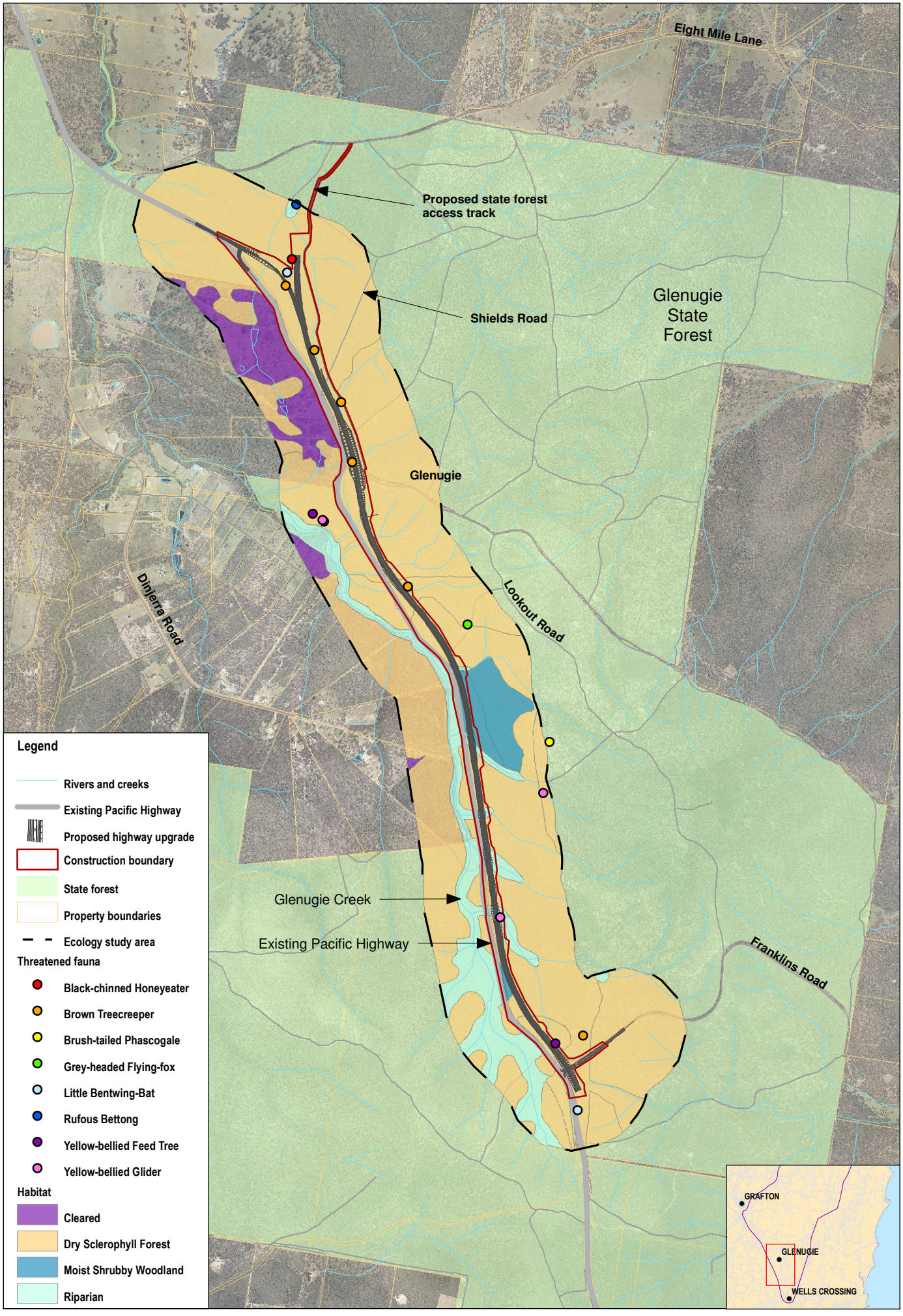
The results of fauna surveys and previous fauna records indicate that 16 threatened fauna species occur in Glenugie State Forest (**Table 4-5** and **Figure 4-7**).

Table 4-5 Recorded and predicted threatened fauna in the study area

Species	Status		Distribution and predicted habitat in the study area
	TSC Act	EPBC Act	
Spotted-tailed Quoll (*Dasyurus maculatus maculatus)*	V	E	Presence inferred from review of regional records and habitat assessment. This species typically exhibits a large home range (in northern NSW the density is reported to be 1 per 4.5km^2). Quolls are recorded from a wide range of habitats including the open forest, woodland and riparian types present in the study area. Den sites have been recorded in caves, rock crevices and hollow logs. Suitably large hollow logs are present throughout the Spotted Gum / Ironbark and Grey Box open forests.
Grey Headed flying fox (*Pteropus poliocephalus)*	V	V	Presence confirmed from one sighting during field survey, and inferred from several records in Glenugie SF (DPI 2008). The species is recorded in a wide range of habitats including the open forest, woodland and riparian types present in the study area in addition to modified landscapes and cultivated areas. The study area is considered a small portion of the foraging habitat available to local populations throughout the region and is not used as roosting habitat.
Bush Stone-curlew (*Burhinus grallarius)*	E		Presence inferred from a review of regional records and habitat assessment. There is a least one historic record from the northern end of Glenugie SF. Not recorded in field surveys. The species is recorded in sparsely grassed, lightly timbered, open forest or woodland and in the study area would be associated with Spotted Gum / Ironbark / Grey Box open forest which occupy the large majority of the landscape through Glenugie SF and surrounding areas.
Hoary Wattled bat (*Chalinolobus nigrogriseus)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. The species is recorded in a wide range of habitats including the open forest and woodland types which dominate the study area and surrounding landscape in addition to adjacent open floodplains and grasslands which may be used for foraging. A forest-dwelling species which roosts in tree hollows in eucalypts.
Little Bentwing-bat (*Miniopterus australis)*	V		Recorded from several locations in the study area during the field survey and also recorded widely in Glenugie SF (DPI 2008). The species is recorded in a wide range of habitats including the open forest types which dominate the study area and surrounding landscape. It is evident from the number of records that portions of the study area comprise important foraging habitat for this species. A predominantly cave-roosting species identified from natural and man-made structures, particularly maternity / breeding sites. No caves or underground shafts occur in the study area and the location of the roost site for this local population is not known. At least one report of tree roosting (Schulz 1997) however given the number of records it is likely that a cave roost occur within a 10-20 km radius of the study area.
Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. Species habitat preferences and roosting requirements as per *M.australis*.
Glossy Black-Cockatoo (*Calyptorhynchus lathami)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. Numerous records noted in the eastern parts of Glenugie SF and throughout Yuraygir NP, although very few records in the actual study area. The species occurrence is widespread in the region and associated with open forest habitats where food resources (*Allocasuarina* spp) are present. Black She-oak

Species	Status		Distribution and predicted habitat in the study area
	TSC Act	EPBC Act	
			(*Allocasuarina littoralis*) is a moderately common component of the Spotted Gum / Ironbark / Grey box open forests which make up the majority of the study area and potential habitat for this species is widespread in the locality. Despite this a search of over 30+ large Forest Oaks along the alignment did not detect any evidence of foraging use by this species. The size of the local population and importance of the study area is not known, although considered low based on this evidence. Large tree hollows (potential nest sites) are present in low abundance along the alignment.
Square-tailed Kite (*Lophoictinia isura)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. The species is recorded in a wide range of habitats including the open forest types which dominate the study area and surrounding landscape. No nest sites were reported from a general traverse of the entire alignment.
Grey-crowned Babbler (eastern subsp) (*Pomatostomus t.temporalis)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. The species is recorded in sparsely grassed, lightly timbered open forest and woodland. They are commonly recorded in open modified rural landscapes in the Clarence Valley. May occur in low densities in the more open habitats throughout the study area. No evidence of the species or nest sites has been identified. The study area is not likely to be important for regional populations.
Black-chinned Honeyeater (eastern subsp) (*Melithreptus g.gularis)*	V		Recorded as uncommon and restricted in the study area, particularly associated with the Grey Box / Spotted Gum habitat types in the northern part of Glenugie SF and adjoining private properties along Eight Mile Lane where low densities were reported. No records directly along the route. Suitable habitat appears widespread although may be of reduced quality due to the widespread removal of mature tree cover and particularly ironbarks from logging). Prefers rough barked trees and decorticating bark typically of Grey Box. Optimum habitat is associated with the Grey Box dominated forest in the central northern part of the study area.
Brown Treecreeper (eastern subsp) (*Climacteris picumnus victoriae)*	V		Recorded as common in restricted locations of the study area, particularly associated with the Grey Box dominated open forest in the central northern half of the alignment and Ironbark dominated open forest in the southern portion of the study area, particularly east of the alignment along Franklins Road. Much of the habitat of this species and indeed reported locations appears to be east of the alignment and would be associated with a higher abundance of tree hollows (required for nesting) and rough-barked Eucalyptus preferred for foraging.
Powerful Owl (*Ninox strenua)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. A widespread species recorded in a range of habitats including the open forest and riparian habitats typical of the study area. Prey species (typically arboreal mammals) are present although limited to Sugar Gliders (*Petaurus breviceps*), Brushtail Possum (*Trichosurus vulpecula*) and Yellow-bellied Glider (*P.australis*). Common ringtail possums (*Psedocheirus peregrinus*) are very scarce and their low density may negatively affect the availability of habitat for Powerful Owls. Similarly large tree hollows required for nesting are uncommon and the habitat within the study area is unlikely to support a high density of Powerful Owls or constitute regionally important habitat.
Koala (*Phascolarctos cinereus)*	V		Not recorded in the study area, presence inferred from a review of regional records and habitat assessment. No evidence of koalas was recorded in the study area despite extensive searches throughout suitable habitat. The presence of Forest Red Gum (*Eucalyptus tereticornis*) and Small-fruited Grey Gum (*E. propinqua*) in very low densities suggests that the habitat is suitable to support small populations of koalas or dispersing and transient individuals, however the study area is considered unsuitable to support a significant population.

Species	Status		Distribution and predicted habitat in the study area
	TSC Act	EPBC Act	
Yellow-bellied Glider (*Petaurus australis)*	V		Recorded from four locations during field surveys within the study area, all associated with or in proximity to riparian areas. Also reported from several locations throughout Glenugie SF (DPI 2008). The association with riparian habitat may be a factor of the higher density of tree hollows in these locations and indeed potential den trees were noted along Glenugie Creek. Evidence of sap feeding (feeding scars) was observed in Grey Box (*Eucalyptus moluccana*) and Orange Gum (*E. bancroftii*). The presence of these species in addition to Bloodwood (*Corymbia intermedia*) (MU 3, 4 and 6) would constitute preferred habitat particularly where this occurs in proximity to Glenugie Creek and other distinctive riparian habitats. Yellow-bellied Gliders were reported on both the eastern and western side of the existing Pacific Highway and large areas of suitable habitat occur to the west of Glenugie Creek. Management measures are required to mitigate the effect of fragmentation from the project on this species.
Brush-tailed Phascogale (*Phascogale tapoatafa)*	V		Recorded from one location during the field survey, in Spotted Gum / Ironbark open forest heavily disturbed from logging and thinning although comprising abundant large logs preferred by this species. Reported in a wide range of habitats including the open forest and woodland types which are well represented in the study area and indeed the wider Clarence Valley and adjoining escarpments along the Pillar Valley and Shark Creek ranges and Yuraygir NP.
Rufous Bettong (*Aepyprymnus rufescens)*	V		Recorded from two locations during the field survey associated with riparian vegetation in the northern half of the study area near Nine Mile Creek and Pheasant Creek. This species is recorded in sparsely grassed, lightly timbered open forest and woodland. The abundance of records reported throughout the northern half of Glenugie SF (DPI 2008) and other reports north of Eight Mile Lane into the Coldstream wetlands suggests that the local population is large centred in the far northern and eastern parts of the study area extending north into private properties along Eight Mile Lane. Records are associated with Nine Mile Creek and also occur to the west of the existing Pacific Highway in this location.



Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007

Figure 4-7: Threatened fauna recorded from targeted surveys

0 1
A4 1:40,000 Kilometres

5. Impact assessment

5.1. Avoidance and minimisation

5.1.1. RTA approach to biodiversity impacts

When planning, designing, constructing and maintaining roads, RTA endeavours to:

- Avoid impacts on habitat, through the planning process.
- Minimise impacts on habitat, through the planning process.
- Mitigate for impacts on habitat, through the use of a range of amelioration measures.

This approach has been adopted for the project, firstly via the initial planning phase which saw a detailed route selection process designed to avoid and minimise impacts on habitat and secondly via the environmental assessment, which incorporates important key design characteristics, and management and monitoring actions designed to mitigate any residual impacts. Further details on these measures as outlined in the following sections.

5.1.2. Route selection process

The route selection process was undertaken during 2006 and 2007. Relevant input into the process and prediction of impacts on terrestrial flora and fauna was a major component of the process. The work completed was designed to effectively identify, describe and map high conservation value features in the landscape. Four criteria were developed to assess the significance of impacts on biodiversity potentially affected by each option, these included:

- Impacts on high quality habitats.
- Assessment of impacts on threatened species habitats and endangered ecological communities (EECs).
- Extent of impacts on SEPP 14 wetlands.
- Severance of wildlife corridors.

The data collection for each criteria provided valuable input into the overall route options assessment, refinement and selection process and was effective in aiding to avoid and minimise significant impacts on regional biodiversity.

Several separate route options were investigated in the Glenugie area to attempt to avoid impacts to the large population of *Eucalyptus tetrapleura* in the project footprint. A detailed assessment of two alternative options was undertaken: an option about 500 m to the east of the existing highway within Glenugie State Forest; and an option on the western side of the existing highway.

The results of this route option study determined the existing option adjacent to the eastern side of the existing highway to have the least overall ecological impact. Although other options would potentially have less impact to individuals of *Eucalyptus tetrapleura* the other options would result in significant impacts to fauna habitats, impose a greater degree of habitat fragmentation and potentially result in significant impacts to Glenugie Creek which flows parallel to the western side of the existing highway.

5.1.3. Key design characteristics

The results of the flora and fauna studies conducted for the route options and concept design phases of the project were used as a tool to refine the project and provide assistance with designing measures to further minimise impacts. This relates specifically to the identified locations of threatened species and habitat of conservation significance including habitat connectivity issues. A summary of the issues identified in the environmental assessment and outcomes include:

- Targeted surveys of the distribution and abundance of the vulnerable species *Eucalyptus tetrapleura* were conducted across the broader locality incorporating the road footprint and remaining areas of Glenugie State Forest. These surveys were designed to identify the size and extent of the local population and provide options for modifying the design footprint where possible to minimise the impact on this species and investigate options for offsetting impacts from the development.
- Input into the identified locations of significant fauna in the study area including habitat connectivity options to provide input into the appropriate density and location of fauna crossing structures that minimise the barrier effect of the road.

5.2. Residual impacts

Residual impacts on flora and fauna include those unavoidable impacts expected on vegetation and habitat in the study area after the selection of the project and refinement of the concept design were completed. Direct and indirect impacts from the project on populations of flora and fauna including threatened species would result from:

- The direct removal of vegetation and fauna habitat.
- Impacts on biological and genetic diversity.
- Loss of endangered ecological communities.
- Loss of threatened species and their habitat.
- Loss of habitat for migratory fauna.
- Edge effects and weed invasion.
- Habitat fragmentation.
- Impacts to fauna movement and behaviour.

- Impacts to riparian habitats.
- Impacts to aquatic habitat.

5.2.1. Loss of native vegetation and fauna habitat

The RTA requires that the conservation values of the study area be considered in the design of the road upgrade such that the proposed footprint is located to minimise removal of remnant vegetation wherever possible, and mitigation measures should be included to minimise the potential for impacts on remaining vegetation. The impacts on vegetation and habitats from the project are detailed in **Table 5-1**. The impacts have been calculated on the full motorway upgrade proposal with a 10 m disturbance buffer and include the proposed new forestry 4WD access road linking Glenugie State Forest to Eight Mile Lane.

- **Table 5-1 Direct impacts on vegetation, habitat and threatened species**

Vegetation community/ type	Area / estimated number of individuals impacted
Vegetation communities	
Map Unit 1: Spotted Gum - Broad-leaved Ironbark Open Forest	33.7 ha
Map Unit 2: Spotted Gum - Square-fruited Ironbark Open Forest	21.7 ha
Map Unit 3: Grey Box - Spotted Gum Open Forest	19.2 ha
Map Unit 4: Scribbly Gum - Bloodwood Open Forest	0.00 ha
Map Unit 5: Swamp Turpentine - Paperbark Riparian Forest	5.3 ha
Map Unit 6: Narrow-leaved Red Gum - Paperbark Open Woodland	5.1 ha
Map Unit 7: Forest Red Gum - Grey Box Forest	0.00 ha
Endangered ecological communities	
Subtropical Coastal Floodplain Forest	5.3 ha
Threatened flora species	
Eucalyptus tetrapleura	36 ha / 6156 individuals
Melaleuca irbyana	3.00 ha / 5 -10 individuals
Fauna habitat	
Dry Sclerophyll Forest	74.7 ha
Riparian Forest	5.3 ha
Moist Shrubby Woodland	5.1 ha
Total vegetation/ habitat impact	**85 ha**

In additional to the direct impacts specified in **Table 5-1**, 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 footprint, as well as impacts from habitat fragmentation affecting wildlife corridors utilised by local threatened fauna species and loss of biological and genetic diversity. In the local context this amount of vegetation/habitat removal is relatively insignificant when comparing the large areas of vegetation which would remain in the local area in surrounding state forests, conservation reserves and private property.

5.2.2. Special management zones

Areas of Glenugie State Forest have been mapped as special management zones due to them being identified as high conservation old growth comprising two separate areas north of Franklins Road on the eastern side of the Pacific Highway totalling about 49 ha. The project footprint includes about five hectares of these special management zones.

5.2.3. Impacts on biological and genetic diversity

The direct removal of vegetation and fauna habitat described and the associated fragmentation of habitat has the potential to have long-term impacts on genetic and biological diversity for flora and fauna species. This impact would be greatest on species with high levels of endemism and in particular species with small restricted home ranges within the study area. Several of the flora and fauna species identified from the field surveys are considered to have a relatively restricted distribution, including *Eucalyptus tetrapleura* and *Melaleuca irbyana*.

Eucalyptus tetrapleura

The population of *Eucalyptus tetrapleura* intersected by the project footprint is estimated to occur over an area of 613 ha (which includes the footprint, surrounding areas and individuals adjacent to the western side of the existing highway) supporting about 103,300 individual trees from all age classes. Additionally there are nearby populations to the south and east not directly linked to the population in the project footprint on private land, in Glenugie State Forest, New Foundland State Forest, Wells Crossing Flora Reserve and Yuraygir State Recreation Area. The total individuals estimated to occur in these populations within about six kilometres of the project footprint is 147,000 over an area of 1010 ha.

The 147,000 individuals within six kilometres of the project footprint could be considered to be within a single population considering the high mobility of some pollinator species such as insects, birds and bats, and wind dispersal of pollen. The total regional population of *Eucalyptus tetrapleura* is known to occur between Glenreagh in the south to Casino in the north within a range of about 100 km north-south and 50 km east-west. 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.

There are estimated to be about 6156 individuals within the project footprint which would potentially be removed including about 36 ha of habitat. This potential removal is estimated to constitute about 4.2 per cent of the local population and between 2.5 and 3.6 per cent of the total known population of the species. This would have impacts to the local distribution of the species, removing part of the local gene pool and 36 ha of known habitat for the species. The project would also result in the further fragmentation between the population on the western side of the existing highway and from populations to the east. A sufficient proportion of the

local gene pool (about 95 per cent) is estimated to remain in the surrounding areas within conservations reserves, state forests and private lands following the proposed impact.

The population is currently fragmented by the existing highway and the project would widen the disturbance width further fragmenting habitats on the western side of the existing highway from populations to the east. However considering the high mobility of some pollinator species such as insects, birds and bats, and wind dispersal of pollen, gene flow is expected to continue across the existing highway and the width of the project. There is estimated to be about 7,100 individuals on the western side of the existing highway, which is likely to have a large enough gene pool to continue to successfully reproduce without inbreeding depressions.

The project is unlikely to significantly impact the local gene pool or lead to inbreeding depressions due to fragmentation based on the above information. Habitat for pollinator species would be removed, however sufficient habitat for large populations of potential pollinator species would remain in surrounding areas.

Melaleuca irbyana

A small population of *Melaleuca irbyana* was recorded in the study area comprising about 31 individuals. Of these up to 10may be impacted from the project, however there is potential to retain more individuals adjacent to the project footprint during construction and reduce the impact to five individuals. The project would fragment the population in the project footprint with individuals retained on both sides of the highway. The population included both seedlings, juvenile and adult plants.

Surrounding the project footprint in the local area there are several populations of *Melaleuca irbyana* recorded on the DECC Atlas of NSW Wildlife (2009), comprising at least 166 individuals. One of the main populations indicated in the records is about 2.5 km north east of the project footprint and comprises 114 individuals on the eastern edge of Glenugie State Forest.

The local population for *Melaleuca irbyana* could be considered to include both the population within the project footprint and the population 2.5 km to the north east, considering the high mobility of potential pollinator species and wind dispersal of pollen. Additionally, there may be other locations of *Melaleuca irbyana* between these two sub-populations which have not been detected. The total population size is estimated to be 145 individuals. Therefore the individuals potentially impacted from the project comprises between three and seven per cent of the local population. However, 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. To mitigate the loss of individuals within the project footprint and prevent significant losses to the local gene pool, it is proposed that seed collection and propagation program be implemented for *Melaleuca irbyana* in close proximity to the project footprint. This population has a relatively

low abundance and is likely to benefit from supplementary plantings within suitable areas of habitat.

The project has potential to contribute to the degree of habitat fragmentation in the local landscape through the direct removal of habitat along a linear stretch of connected vegetation, particularly given the location of Glenugie State Forest in the context of the network of connected habitats in the landscape. This impact would have a potential effect on the movements and dispersal capabilities of some fauna species particularly those with larger home ranges such as the Spotted-tailed Quoll (*Dasyurus maculatus*), Rufous Bettong (*Aepyprymnus rufescens*) and large forest owls. Highly mobile species such as larger birds and bats are less likely to be affected and species with smaller or restricted home ranges may be more impacted by genetic isolation rather than normal movements.

Measures to mitigate these impacts have been addressed via the appropriate placement of dedicated and incidental fauna underpasses to minimise the barrier effect of the dual carriageway.

5.2.4. Loss of endangered ecological communities

Of a total vegetation loss of 85 ha, about 5.3 ha is part of an endangered ecological community (EEC) listed under Schedule 1, Part 3 of the TSC Act, namely Subtropical Coastal Floodplain Forest (refer **Table 5-1**). An assessment of significance of impacts on this EEC was conducted in accordance with the *Draft Guidelines for Threatened Species Assessment* (DECC and DPI 2005). The results are summarised below, with full details provided in Appendix B.

- The loss of 5.3 ha of this EEC represents a relatively small proportion of the total remaining area of this EEC in the local area.
- The Comprehensive Regional Assessment Aerial Photographic Interpretation (CRAFTI) (Resource and Conservation Division 2001) has mapped about 2211 ha of vegetation with affinities to Subtropical Coastal Floodplain Forest within about a 10 km radius of the project footprint.
- The project would result in the removal of about 0.25 per cent of the local distribution of this community.
- Areas of this EEC on the eastern side of the project footprint would be further fragmented from areas of this EEC along Glenugie Creek to the west of the existing highway.
- Areas of this community identified to the east and north of the study area within Glenugie and Pine Brush State Forest and areas along Glenugie Creek on the western side of the existing highway would remain following the project.
- This community is not at the limits of the known distribution for this EEC.

- 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.

5.2.5. Loss of threatened species and their habitat

The loss of vegetation and fauna habitat would negatively affect several populations of threatened flora and fauna species through the direct loss of known habitat, increasing the fragmentation of habitat and creating barriers to movement and dispersal of individuals. An assessment of significance of impacts was conducted for known and potential subject species (i.e. listed threatened species) in accordance with the *Draft Guidelines for Threatened Species Assessment* (DECC and DPI 2005) and in the National context in accordance with the *Significant Impact Guidelines for Matters of National Environmental Significance* (DEH 2006) (refer Appendix B and Appendix C for details). A summary of the conclusions of these assessments is presented in **Table 5-2.**

5.2.6. Loss of habitat for migratory species

No listed migratory bird species (EPBC Act) were identified from the field investigation, however the Regent Honeyeater (*Xanthomyza phrygia*) and White-throated Needletail (*Hirundapus caudacutus*) are considered to potentially occur based on the habitat assessment. As an aerial forager this species is generally observed in the air and has no specific or documented habitat preferences. There is no evidence to suggest that an area of important habitat exists in the study area for this species.

Table 5-2 Summary of assessment of significance for listed species and communities

Species/ community	Conservation status		Conclusions of assessment
	Cwlth	NSW	
Threatened Flora			
Square-fruited Ironbark *Eucalyptus tetrapleura*	V	V	■ There are estimated to be about 6156 individuals within the project footprint occurring within about 36 ha of habitat. ■ The 147,000 individuals estimated to be present within six kilometres 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. ■ 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. ■ This potential removal is estimated to constitute about 4.2 % of the local population and between 3.6 % and 2.5 % of the total known population. ■ 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. ■ Habitat for pollinator species would be removed, however sufficient habitat for large populations of potential pollinator species would remain in surrounding areas. ■ The project would result in the removal of up to 36 ha of known habitat for Eucalyptus tetrapleura. This constitutes about 3 % of the total known habitat for Eucalyptus tetrapleura identified in the field surveys for this project. ■ Eucalyptus tetrapleura 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 of (DECC 2009) about 14 km to the south and 70 km to the north. ■ 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. ■ To mitigate the RTA will develop a biodiversity offset strategy in consultation with DECC and Department of Planning. This strategy will aim to maintain or improve biodiversity values in the project area in the long-term including populations of Eucalyptus tetrapleura.

Species/ community	Conservation status		Conclusions of assessment
	Cwlth	NSW	
Weeping Paperbark *Melaleuca irbyana*	-	E	■ A small population of *Melaleuca irbyana* was recorded in the study area comprising about 31 individuals of which up to 10 may be impacted from the project however there is potential to retain more individuals adjacent to the project footprint and reduce the impacts to 5 individuals. ■ The local population for *Melaleuca irbyana* is considered to extend beyond the study area due to the high mobility of potential pollinator species and wind dispersal of pollen. ■ A population of *Melaleuca irbyana* 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. ■ The total population size is estimated to be as large as 145 individuals, therefore potential impacts comprises between 3 and 7 % of the local population. ■ The project would potentially remove between 16 and 32 % of the sub-population in the project footprint which is considered a relatively significant removal, however these impacts can potentially be mitigated. ■ The project would result in the removal of about 3 ha of known *Melaleuca irbyana* habitat, from the 17 ha of habitat estimated to be present in close proximity to the project footprint. ■ 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. ■ The project would result in fragmentation of the sub-population within the project footprint, with individuals retained on either side of the project. ■ 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. ■ 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 *Melaleuca irbyana*. Individuals impacted by the from the project will be translocated into adjacent habitats within the road boundary.
Threatened fauna			
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 (*Corymbia henryi*) 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.

Species/ community	Conservation status		Conclusions of assessment
	Cwlth	NSW	
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.
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
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.

Species/ community	Conservation status		Conclusions of assessment
	Cwlth	NSW	
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 (*Eucalyptus moluccana*), 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.
Rufous Bettong		V	The species is recorded in sparsely grassed, lightly timbered open forest and woodland and particular favours 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 (*Imperata cylindrica*) for shelter and nesting. The project would remove 74.7 ha of open forest, 5.1 ha of woodland and 5.3 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. 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.
Woodland Birds		V	The project would remove 74.7 ha of open forest and 5.1 ha of woodland potentially suited to these species. The loss would likely impact on the home range territory of several pairs, remove a percentage of the shelter and foraging resources for these birds and potentially disrupt a breeding season. The number of animals affected in relation to the size of local population is not known, however records are widespread and it could be reasonably expected the proportion of the population impacted would be minor and not lead to a significant impact on the population as a whole.

Species/ community	Conservation status		Conclusions of assessment
	Cwlth	NSW	
Bush Stone-Curlew		E	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.

V= vulnerable, E= endangered

5.2.7. Edge effects and weed infestation

A review of edge effects associated with roads (Bali 2005) summarised data from several sources in identifying the potential impacts on adjacent terrestrial and aquatic habitats. The following effects were documented:

- Increased annual mortality during construction.
- Increased annual mortality from collisions with vehicles.
- Modified animal behaviour.
- Altered physical environment.
- Altered chemical environment.
- Spread in exotic species.
- Increase alteration and use of habitats by humans.

It is evident from the studies conducted to date that the type and extent of edge effects is highly variable. This is not surprising considering that edge effect intensity may be related to abiotic and biological factors such as age, vegetation structure, aspect, matrix type and management history (Murcia 1995).

There is a clear tendency of edge effects to vary with vegetation structure; they are greatest at new or induced edges and less obvious at old or inherent edges (Bali 2005). The maximum extent of edge effects for reliable indicator species is up to 50 m from the forest edge (Murcia 1995). Edge effects are expected to be created along the entire project footprint where ‘new’ edges would be created through Glenugie State Forest. Edge effects would be greatest on the eastern edge of the project footprint as these areas would be relatively un-effected by the existing edge effects along the edge of the existing highway.

The extent of possible edge effect impacts for the project were calculated based on 0.6:1 ratio consistent with the data presented by Bali (2005) (i.e. 0.6 x 50 m wide) along the length of the eastern side of the project footprint only (seven kilometres). This calculation resulted in a total area of impact of about 21 ha. These impacts would be most profound for riparian vegetation communities (many of which are EECs) where invasive weed species such as *Lantana camara* are likely to greatly increase in abundance with higher light availability and potentially shade out native understorey species and affect fauna habitats. *Melaleuca irbyana* which would be 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 mitigation and rehabilitation measures associated with the construction and operational stages of road development (Bali 2005). The highest priority measures aim to minimise and intersect surface water run-off into adjacent remnant vegetation. Dense roadside plantings using a diversity of local indigenous plant species would reduce the affects of rapid weed invasion into disturbed edge habitats.

5.2.8. Habitat fragmentation

The division of larger patches of remnant habitat into two or more smaller areas has significant impacts to native flora and fauna species, including affecting movement corridors, genetic exchange, decrease the available area of habitat and increasing edge effects. Large areas of continuous habitat are particularly important for species which have large habitat ranges such as Spotted-tailed Quoll (*Dasyurus maculatus*) and Large Forest Owls as these areas provide an adequate area of foraging habitat, are more likely to support suitable roosting and nesting habitats, and increase the carrying capacity of the area increasing the chances of finding a mate. Large areas of contiguous vegetation also decrease the likelihood of local extinctions from stochastic events such as wildfire and disease, as individuals can re-populate areas more effectively.

The impact of habitat fragmentation by roads is well known (Andrews 1990). Typically these pressures occur at fine spatial scales such as forest stands, but also impact cumulatively over time (Burris and Canter 1997) on the structure and function of larger forest ecosystems. Potential impacts from habitat fragmentation are detailed in Andrews (1990) and include:

- Alteration of hydrology and siltation of aquatic habitats.
- Impacts on species with localised habits.
- Edge effects.
- Barrier effects.

The landscape surrounding the study area supports several very large areas of habitat associated with the production forests of Glenugie State Forest, Newfoundland State Forest and conservation reserves such as Yuraygir National Park in addition to natural vegetation on private rural properties. This is a reflection of the low fertile soil types and terrain which is not suited to agriculture in contrast to the fertile soils on the Clarence River floodplain which have resulted in extensive clearing and fragmentation of vegetation. The habitat to the west of the project area becomes increasingly more fragmented in lower elevated lands and private property while Glenugie State Forest continues extensively to the east of the project area.

Impacts associated with the barrier effect of new roads are well documented. This factor has potential to impact on typical fauna movements in the vicinity of the road, in turn negatively impacting on important life-cycle events such as foraging, breeding and dispersal. The new road would contribute to the cumulative reduction in habitat connectivity similar to the existing Pacific Highway in this location and would have the greatest potential impact on ground-dwelling terrestrial fauna and species with large home-ranges such as the Spotted-tailed Quoll. More mobile species such as bats and birds have better opportunities to move across the landscape and access habitat fragmented by roads.

Measures to reduce the impact on connectivity have been considered in the development of a fauna crossing strategy (Section 6) and include the provision of dedicated, combined fauna and incidental underpass structures in addition 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.

5.2.9. Impacts on fauna movements and behaviour

Wildlife corridors

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

Taylor (1991) discusses some useful advantages of retaining strips of vegetation between larger patches of forest, using state forests as an example. These principles are equally applicable to vegetation on private property, crown land and reserves. Some important aspects discussed by this author suggest that retained strips of habitat:

- Allow fauna to re-colonise regenerating habitats as they become available.
- Ensure that populations in larger patches do not become isolated.
- Provide shelter and nesting resources for those species that can utilise regrowth for feeding although require adjoining mature forest for shelter and breeding resources.

The location of wildlife corridors has been investigated as they relate to the project.

The entire highway alignment occupies a portion of Glenugie State Forest. This forestry land extends further to the east and west totalling over 3,400 ha in area. Glenugie State Forest has been identified as a 'key habitat' and is positioned at a strategic location in the landscape being a connecting link from the coast via Newfoundland State Forest and Yuraygir National Park through to the west into Bom State Forest and dry open forest habitats on freehold land in the Coutts Crossing and Shannondale areas. At the north eastern end the forest there are fragmented links to Sandy Crossing and eventually the Pillar Valley range. Given the expanse of habitat surrounding the study area specific linear wildlife corridors are actually very limited. The only identifiable corridor occurs immediately north of the project traversing east-west from Glenugie State Forest and adjoining the southern end of Eight Mile Lane this corridor is not directly impacted by the proposed Glenugie Upgrade however is applicable to concept route of the Wells Crossing to Iluka Road project and has been dealt with in the assessment for that 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. 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 mitigation. The review of key habitats, corridors and habitat patch network was used to develop appropriate specifications for the type and location of proposed fauna crossing structures within the final road design. Further detail on the fauna crossing strategy is provided in Section 6.

Fauna mortality

By effectively 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 current Pacific Highway which is currently impacting on populations. Further, the distribution of fauna collisions or 'black spots' is also difficult to identify, and indeed impact locations may in fact be widespread and not isolated to particular locations or patterns may emerge over time in association with wildlife corridors.

Fauna crossing structures, exclusion fencing and signage has been widely used to minimise this impact and consideration of the number and location of these has been incorporated into the project.

Animal behaviour

Impacts associated with the barrier effect of new roads as well as increased traffic noise and lighting is well documented. These factors would effectively impact on typical fauna movements in the vicinity of the road, in turn negatively impacting on important life-cycle

events such as foraging, breeding and dispersal. Measures to reduce this impact may include the provision of dense landscape planting.

5.2.10. Impacts on riparian habitats

The following section refers to impacts from the project on riparian habitats. Riparian habitat in the study area is restricted to very narrow linear strips of vegetation along Glenugie Creek and associated tributaries (<100 m wide) which are distinctive from the surrounding dry open forest. Impacts on riparian vegetation would occur directly in the road footprint at proposed creek crossing locations and indirectly through changes to local hydrological regimes and edge effects, including possible shading or proximal vegetation and potential weed invasion.

The exact area to be directly lost from the project is equal to around five hectares. Impacts on riparian habitats adjoining the road footprint are to be mitigated through minimising the construction footprint at all proposed creek crossings, installing run-off storage structures, minimising erosion and rehabilitation post-construction through plantings of locally indigenous riparian species.

5.2.11. Impacts on aquatic habitats

The project would traverse Glenugie Creek and several unnamed watercourses, which provide habitat for fish and other aquatic organisms. Potential impacts on aquatic habitats include overshadowing, pollution of waterways, change to the hydrological regime, and removal of in-stream woody debris. Removal of in-stream woody debris (snags) 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 can favour exotic species. Predation by exotic species and in particular the Plague Minnow (*Gambusia holbrooki*) is also a threatening process. Increased sedimentation and erosion during construction is also considered a threatening process under the *Fisheries Management Act* 1994 (FM Act). Increased suspended solids can impact fish and macroinvertebrate abundance through clogging gill structures and benthic smothering. Increased particulates in the water column can also reduce light penetration, which may limit plant growth and influence predator foraging behaviour.

Increased road runoff and pollutants entering the waterways during construction could potentially have a toxic effect on aquatic habitats and biodiversity. However, these can be mitigated to reduce the risk.

The design for the project has been developed so that the existing hydrological regime would generally be maintained through the use of culverts where required. Detailed design of culverts at Glenugie Creek would provide appropriate fish passage. 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 main operational activity that has the potential to impact watercourses is increased traffic flow, which may lead to increased pollutant loads in road run-off. Road run-off can contain a variety of pollutants that may impact the aquatic environment, including nutrients, heavy metals, pesticides, herbicides and petroleum hydrocarbons. Management and impact mitigation measures have been proposed to reduce the amount of pollutants entering the waterways. For example, runoff from the project would be directed to detention basins in sensitive environmental areas to improve water quality before being discharged to drains and then to the local waterways. The operational basins would be located in positions alongside the identified water courses, to protect sensitive environmental areas from an unexpected spill.

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 (*Marccullochella 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.

The preferred habitat of the Oxleyan Pygmy Perch is swamps, creeks and lakes of coastal ‘wallum’, which are usually acidic, with low salinity, low conductivity, and are often darkly stained. The Purple-spotted Gudgeon prefers slow flowing deeper waters among aquatic vegetation where suitable submerged objects are available for spawning. The preferred habitat of the Eastern Freshwater Cod is clear, flowing streams with rocky beds, deep holes with plenty of boulders or large woody debris.

The greatest potential for impact on local waterways is during construction. The adoption of appropriately designed and maintained water quality controls and protection measures would be implemented to minimise impact on aquatic habitats.

5.3. Key threatening processes

The TSC Act and FM Act list Key Threatening Processes (KTP) as activities or processes that could either:

a) Adversely affect threatened species, populations or ecological communities.

b) 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 5-3** along with proposed measures to mitigate impacts.

Table 5-3 Key threatening processes related to the project

Key threatening process (KTP)	Type of threat	Level of threat	Potential impacts	Impact mitigation measures
Invasion and establishment of exotic vines and scramblers	Weed	High	Exotic Vines and Scramblers were not abundant in the study area, however a potential future problem in gully areas impacted by vegetation loss and edge effects.	Weed management are to be developed as part of the Construction and Operation Environmental Management Plans (Section 6.2.5)
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 are to be developed as part of the Construction and Operation Environmental Management Plans (Section 6.2.5)
Invasion of native plant communities by exotic perennial grasses	Weed	High	Several exotic perennial grasses were identified in disturbed edges of the existing highway and trails through bushland areas. These species are negatively associated with edge effects.	Weed management are to be developed as part of the Construction and Operation Environmental Management Plans (Section 6.2.5)
Invasion, establishment and spread of Lantana camara	Weed	Very High	A majority of the moister vegetation communities in the study area have moderate infestations *Lantana camara*, 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 are to be developed as part of the Construction and Operation Environmental Management Plans (Section 6.2.5)
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 (Section 6).
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 (Section 6).

Key threatening process (KTP)	Type of threat	Level of threat	Potential impacts	Impact 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 (Section 6).
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 (Section 6).
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 study area (Section 6.2.8).
Introduction of the Large Earth Bumblebee (*Bombus terrestris*)	Pest animal	Low	It is unlikely the project could lead to the introduction of large earth bumblebee to the study area	Ensuring construction equipment has been washed down before entering the study area (Section 6.2.8).
Invasion and establishment of the Cane Toad	Pest animal	Low-Moderate	The project may contribute to the invasion and establishment of cane toad.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration (Section 6).
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 (Section 6).
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 (Section 6).
Predation by the Plague Minnow (*Gambusia holbrooki*)	Pest animal	Low-Moderate	The project may contribute to additional predation from Plague Minnow.	None known. Difficult to prevent
Predation, habitat degradation, competition and disease transmission by Feral Pigs (*Sus scrofa*)	Pest animal	Low-Moderate	The project may contribute to additional presence of Feral Pigs in the study area through habitat fragmentation.	The proposed mitigation measures would limit impacts from this KTP, in particular weed management and habitat restoration (Section 6).

Key threatening process (KTP)	Type of threat	Level of threat	Potential impacts	Impact mitigation measures
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 (see Section 6.2.7)
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 placed in adjacent habitats (Section 6.2.1).
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. Mitigation measures are detailed in Section 6.2.1.
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. Mitigation measures are detailed in Section 6.2.1.
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. Mitigation measures are detailed in Section 6.2.1 and 6.2.3.
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 (Section 6.2.1 and 6.2.3)
Infection by *Psittacine circoviral* (beak & 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 study area (Section 6.2.8).
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 study area (Section 6.2.8).

Key threatening process (KTP)	Type of threat	Level of threat	Potential impacts	Impact mitigation measures
Infection of native plants by *Phytophthora cinnamomi*	Disease	Moderate	There is potential for this disease to be spread throughout the study area from construction machinery.	Ensuring construction equipment has been washed down before entering the study area (Section 6.2.8).
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 (Section 6)
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 (Section 6)
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 (Section 6)
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 (Section 6)
Predation of native fish by exotic species	Pest Animal	Low	Predation by exotic species such as *Gambusia holbrooki* (mosquito fish) is most likely to occur in highly disturbed freshwater streams	Disturbances to water quality and habitat needs to be minimised and monitored where appropriate (Section 6)
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

5.4. Cumulative impacts

5.4.1. Regional scale cumulative impacts

At the landscape scale, the major potential ecological impacts of increasing road networks are likely to be the disruption of landscape processes and loss of biodiversity (Forman & Alexander 1998). An extensive and complex road network is already in existence in the study area region and the proposed new road would be a contributor to this network. However, as the new road would in effect traverse a landscape which is already dominated by human activities, such as farming, logging and rural development, as opposed to a completely natural forested landscape, the cumulative impacts on biodiversity could reasonably be expected to have a low detectability.

Notwithstanding this fact, the new road would contribute to an increased density of roads versus remaining habitat in the region. Impacts could be offset to a degree by the development of a biodiversity offset strategy. Any such efforts should be based on the objective of maintaining or improving biodiversity values in the project area in the long-term.

5.4.2. Cumulative ecological impacts of Pacific Highway Upgrade Program

An estimate of the cumulative ecological impacts of the 13 existing Pacific Highway upgrade projects is provided in **Table 5-4**. Other Pacific Highway upgrade projects have the potential to impact *Eucalyptus tetrapleura* occurring to the south of the project. Every effort will be made to avoid and/or reduce potential environmental impacts during the environmental assessment and refinement of the concept design for those projects.

Table 5-4 Estimated cumulative vegetation clearing for Pacific Highway Upgrade Program

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)
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
Total		361.4	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

5.5. Impact summary

Mitigation measures have been considered and recommended for each of the reported impacts imposed by the project. These are addressed in Section 6. A summary of the likely impacts and relevant section of the discussion are detailed in **Table 5-5**.

Table 5-5 Impact summary for the project

Potential impact	Level of impact/ significance	Recommended mitigation measures
Loss of biological and genetic diversity	Moderate	Section 6.2
Loss of native vegetation and fauna habitat	High	Section 6.2.1, 6.2.8
Loss of endangered ecological communities	Low	Section 6.2.2, 6.2.8
Loss of threatened species	High	Section 6.2.1, 6.2.3, 6.2.8 , 6.3
Loss of migratory species	Low	Section 6.2.1, 6.2.8
Edge effects and weed invasion	Moderate	Section 6.2.4
Habitat fragmentation	Moderate-High	Section 6.2.5
Impacts to wildlife corridors	Low	Section 6.2.5
Impacts to Riparian Habitats	Low-Moderate	Section 6.2.6
Regional scale cumulative impacts	Low-Moderate	Section 6.3
Increased sedimentation and erosion during construction	Moderate	Section 6.2.9
Increased pollution	Moderate	Section 6.2.9
Removal of instream woody debris	Low	Section 6.2.12
Loss of aquatic and riparian habitats	Moderate	Section 6.2.10

6. Recommended management measures

6.1. Management aims

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

- 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.

In accordance with the RTA's Code of Practice for Water Management: Road Development and Management (RTA 1999), an Environmental Management Plan (EMP) needs to be prepared for all construction and maintenance activities. The EMP's would include a Soil and Water Management Plan (SWMP), which would be created to document methods to limit the movement of sediment and controls to remove sediment from runoff prior to discharge to downstream watercourses.

The SWMP would be prepared during the detailed design stages and would comply with principles and practices in:

- RTA (1998) *RTA Road Design Guide,* Section 7 "Stormwater Management and Drainage Design" and 8 "Erosion and Sedimentation".
- Department of Housing (2004), *Managing Urban Stormwater: Soils and Construction.*

The EMPs would aim to prevent and/or limit the potential impacts and risks to aquatic ecology and water quality incorporating (but not limited to) the following control measures outlined below:

- Retention of large woody debris within watercourses where possible.
- Instream structures such as bridges and culverts would be designed and managed to minimise any potential impact to flow regimes and fishways would be constructed at potential barriers to enable the migration of fish and macroinvertebrates during construction and operation where applicable.
- Riparian and aquatic habitat would be protected during construction works and any areas of riparian vegetation impacted by construction would be rehabilitated.

6.2. Mitigation strategies and design features

The condition of the vegetation and fauna habitats along the study area and the nature of the project suggest that there is potential for significant impacts on biodiversity. Therefore particular care and consideration is required during each phase of the project (i.e. pre-construction, construction and road operation) to minimise threats and conserve areas of conservation value to flora and fauna. The following sections provide advice and recommendations to achieve this objective.

6.2.1. Native vegetation and fauna habitat loss

Mitigation measures to minimise impacts from the loss of native vegetation and fauna habitat includes a range of general measures including:

- Vegetation would only be cleared where required and retained vegetation would be clearly marked and protected from construction activities, this is particularly important in riparian areas.
- Installation of barrier fencing/ taping and signage to mark the limits of clearing (i.e. “no-go” areas) outside the footprint to ensure that vehicles and other direct disturbances associated with the road construction, such as construction compounds and stockpile sites, do not enter adjacent areas of vegetation outside the footprint, particularly in areas where threatened flora species are present and in riparian areas where EECs are present.
- Pre-clearance surveys would be undertaken to flag 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.
- Vegetation management measures would be implemented for retained areas of vegetation, 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 suitable branches.

- Native vegetation cleared from the footprint is to be mulched along with the collection of topsoil to preserve the soil stored seed bank for reuse in rehabilitation works and erosion control.
- 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.
- Implement mitigation measures to avoid the spread of weeds and plant pathogens.
- Implementation of soil erosion and sedimentation control measures.
- These general mitigation measures to minimise impacts to vegetation and fauna habitat would be integrated into the FFMP and CEMP for the project.

6.2.2. Loss of endangered ecological communities

One endangered ecological community (EEC), namely Subtropical Coastal Floodplain Forest, is present along some watercourses in the project footprint. This EEC 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 to 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. The project would result in the removal of up to 5.3 ha of Subtropical Coastal Floodplain Forest.

6.2.3. 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 6-1.**

Table 6-1 Avoidance, mitigation and offset measures for threatened species

Threatened species	Avoidance and impact mitigation measures
Square-fruited Ironbark *Eucalyptus tetrapleura*	• Within the population area of *Eucalyptus tetrapleura* the limits of the extent of clearing for the project would be clearly identified to avoid any accidental incursions or impacts to *Eucalyptus tetrapleura* and any areas or individuals trees adjacent to the project footprint with potential to be retained would be identified and protected. • A suitable offset for the project will be developed in consultation with DECC and Department of Planning. Areas that support large populations of *Eucalyptus tetrapleura* are the primary focus for establishing a suitable offset area.

Threatened species	Avoidance and impact mitigation measures
Weeping Paperbark *Melaleuca irbyana*	• Flagging of *Melaleuca irbyana* plants to be retained along the edges of the project footprint would be conducted prior to clearing for construction and strict protocols implemented to avoid direct impacts where possible. In particular several *Melaleuca irbyana* on the edge of the road batters should be protected from direct impacts. • A rehabilitation/translocation strategy is to be prepared for *Melaleuca irbyana* 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. • Any *Melaleuca irbyana* within the project footprint should be translocated to adjacent areas of habitat. Translocation of *Melaleuca irbyana* is likely to be successful given appropriate preparation, management and maintenance considering the suckering habit of this species. • A monitoring program would be developed to assess the health and development of transplanted individuals and supplementary plantings of *Melaleuca irbyana* in habitats surrounding the project footprint. • 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. • 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. • A suitable offset for the project will be developed in consultation with DECC and Department of Planning.
Threatened Fauna	• 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. • 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. • 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. • Provide dedicated, combined and incidental fauna underpass structures as well as fauna exclusion fencing at key locations identified to target the range of large, medium and smaller species present. • Provide canopy rope crossings at key locations identified to target the Yellow-bellied Glider and common glider species. • 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.

Threatened flora

Measures to avoid, mitigate and offset the direct impacts to threatened flora species are detailed for each species in **Table 6-1** 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 surveys are recommended to target such species which 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, Maudia triglochinoides, Centranthera cochinchinensis,* and *Tylophora woollsii.*

An additional survey in late spring or early summer could be integrated as part of the pre-clearance surveys and any populations identified could be included in any future protection, seed collection or translocation programs that are recommended as far as possible in accordance with any priority actions in species recovery plans.

Threatened fauna

Mitigation measures for threatened fauna species includes many of the mitigation measures listed above in Section 6.2.1 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 species with the aim of assessing the impacts of the project on select threatened fauna species (i.e. target species) in addition monitoring the efficacy of the proposed fauna 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 lathami*) or Large Forest Owls and any den sites for the Yellow-bellied Glider 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.

6.2.4. 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 these clearing activities 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.

6.2.5. 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.

6.2.6. Management of habitat fragmentation and fauna crossings

The impacts of habitat fragmentation would be minimised through a range of mitigation measures including restoration of road verges with locally indigenous flora species and rehabilitation of areas disturbed by the project. Where drainage structures can be designed to avoid riparian vegetation, riparian corridors would be maintained.

The potential impacts of the project on fauna movement and habitat connectivity was considered in the selection of drainage and fauna crossing structures to be incorporated into the project design. Factors considered in selecting the locations and types of drainage and fauna crossing structures included:

- The types of fauna species known to occur or potentially occurring in the study area.
- The landscape elements of the project such as habitat types and natural habitat connectivity adjacent to the project corridor.
- The locations of drainage structures under the existing highway that can be linked to future structures.
- The use of fauna exclusion fencing.

A summary of the proposed approach for addressing fauna movement and habitat connectivity issues is presented in **Table 6-2**.

Table 6-2 Summary of considerations addressed in the fauna crossing strategy

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.

The strategy for fauna movement and habitat connectivity must accommodate fauna using open forest and riparian habitats. To meet this need, opportunities have been extensively explored for including dedicated underpass structures in dry, fill areas, in addition to drainage structures in riparian areas. This approach has resulted in the following types of structures being incorporated into project design:

- Fauna underpass structures at important open forest and riparian locations (**Table 6-3**).
- Canopy rope overpasses at strategic locations for arboreal fauna (**Table 6-4**).

The proposed structures would be incorporated into the project for both the full motorway upgrade and the likely initial staging.

Table 6-3 refers to the following three types of underpass structures:

- Dedicated fauna structures – Structures that are designed specifically for fauna passage.
- Combined fauna structures - Culvert structures that are designed for the dual purpose of drainage and fauna passage. These structures facilitate fauna passage via the inclusion, within a drainage culvert, of special features such as a raised bench or lowered central floor for elevated dry passage or a raised out cell that remains dry during normal rainfall but may take flow during heavy rainfall.
- Incidental fauna structures - Drainage structures, including box or pipe culverts, that are large enough to accommodate fauna passage.

The locations of the proposed fauna passage structures for the project are shown in **Figure 6-1**. 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.

Table 6-3 Underpass structures proposed for fauna passage

Chainage	Structure[1]	Fauna impact mitigation measure	Comments	Link with existing 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 include Rufous Bettong, Brush-tailed Phascogale, and Bush Stone-Curlew. 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 include 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 ϕ2.4 pipe culvert	Combined fauna passage (FC) associated with riparian habitat. Fauna exclusion fencing.	Threatened fauna targeted include 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. Threatened 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.	Threatened 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.
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.	Threatened 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 ϕ1.050 pipe culvert	Incidental fauna (FI) structure.	Targets small mammals, reptiles and frogs.	Linked with existing structure at ch.7320 (3 x 750 mm pipes) via fauna fencing.
7395	4 x ϕ1.2 pipe culvert with outer pipe raised	Dedicated fauna (FD) structure raised to provide dry passage for small fauna during wet periods.	Targets small mammals, reptiles and frogs.	Linked with existing structure at ch.7420 (3 x 900mm pipes) via fauna fencing.

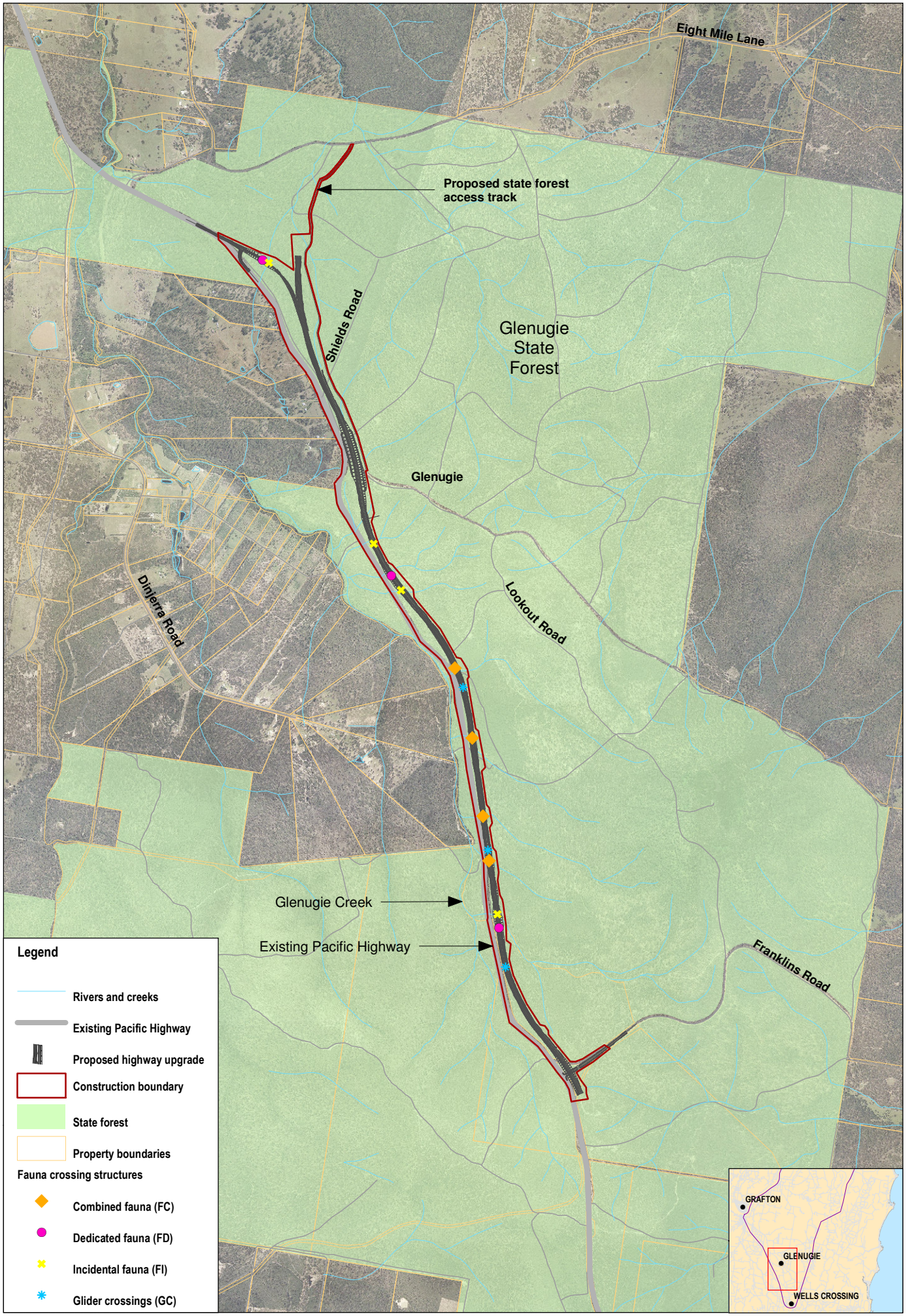
Chainage	Structure[1]	Fauna impact mitigation measure	Comments	Link with existing highway structure
7680	3 x ϕ1.2 pipe culvert. Install 0.1 m lip upstream of one cell to make one cell dry	Incidental fauna (FI) structure.	Targets small mammals, reptiles and frogs.	Linked with existing structure at ch.7690 (2 x 1.2 m culverts) via fauna fencing.
10040	4 x ϕ1.2 pipe culvert (on ramp)	Incidental fauna (FI) structure associated with Nine Mile Creek riparian habitat.	Targets 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 ϕ1.2 pipe culvert located off creek for dry passage	Dedicated fauna (FD) structure positioned for dry passage during wet periods.	Targets 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 are part of both the full motorway style upgrade proposal and the likely initial staging. The structures would be constructed during the likely initial staging.

Table 6-4 Canopy rope structures proposed for fauna passage

Chainage	Staging design structure[1]	Motorway style design structure[1]	Existing 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. Subject to detailed design.



Fauna crossing structures to be confirmed at detail design

Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007

Figure 6-1: Fauna crossing structures

Long-term monitoring of fauna underpass structures has shown success for a range of small to medium sized fauna in eastern Australia (e.g. 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.

6.2.7. Management of riparian and aquatic habitats

Impacts to riparian and associated vegetation communities would be mitigated through the implementation of specific design attributes. The project would be designed to minimise impacts to hydrological regimes. Specific impact mitigation measures include:

- Changes to existing surface and ground water levels should 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 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.

6.2.8. 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.

6.2.9. 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). Further details of erosion and sediment controls to be implemented for the project are provided in Section 7.6.3 of the environmental assessment.

Primarily, the area of disturbance would be minimised, reducing the potential for erosion. Areas that are disturbed should be seeded to provide temporary soil stabilisation and prevent windblown dust from entering waterways. Straw/ cane or other mulch and other suitable techniques should be used to protect exposed soil surfaces and to facilitate grass growth. The

shaping of land should be designed to improve drainage and minimise the gradient and length of slopes.

Soil stockpiles should be located upon flat areas at the site with the height and slope of soil stockpiles limited, located away from hazardous erosion locations. Sediment fences, sediment traps, sandbags and/or stacked hay bales covered in geotextile materials should be constructed on upstream slopes, catch drains and road drains to slow flow and prevent erosion from entering waterways. Catch drains at the downstream boundaries of construction activities (where appropriate) should be construction to ensure containment of sediment laded run-off and diversion towards treatment.

Instream disturbance should be managed and mitigated where appropriate. Silt curtains should be deployed *in situ*, where dredging and excavation of sediments is occurring, to limit the risk of sediment plumes and increased turbidity. Regular water quality monitoring should be undertaken during construction and operation to ensure water quality values and environmental assets are maintained both upstream and downstream of the construction area.

6.2.10. 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.

6.2.11. Key threatening processes

Key threatening processes (KTPs) are listed in **Table 5-3** along with reference to proposed mitigation measures. The KTPs which 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.

6.2.12. Management of 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 for vegetation loss, EEC loss, threatened species and wildlife corridors.

6.3. 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 flora and fauna 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.

6.4. Biodiversity offsetting

6.4.1. Overview

The RTA aims to:

- Avoid impacts on habitat, through the planning and design process.
- Minimise impacts on habitat, through the planning and design process.
- Mitigate impacts on habitat through the use of a range of strategies.

This approach has been adopted in the planning and design of the project. Although the mitigation and management measures would be incorporated in the project, there are some residual impacts that cannot be avoided such as:

- A loss of native vegetation including vegetation which comprises the state and nationally listed 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.

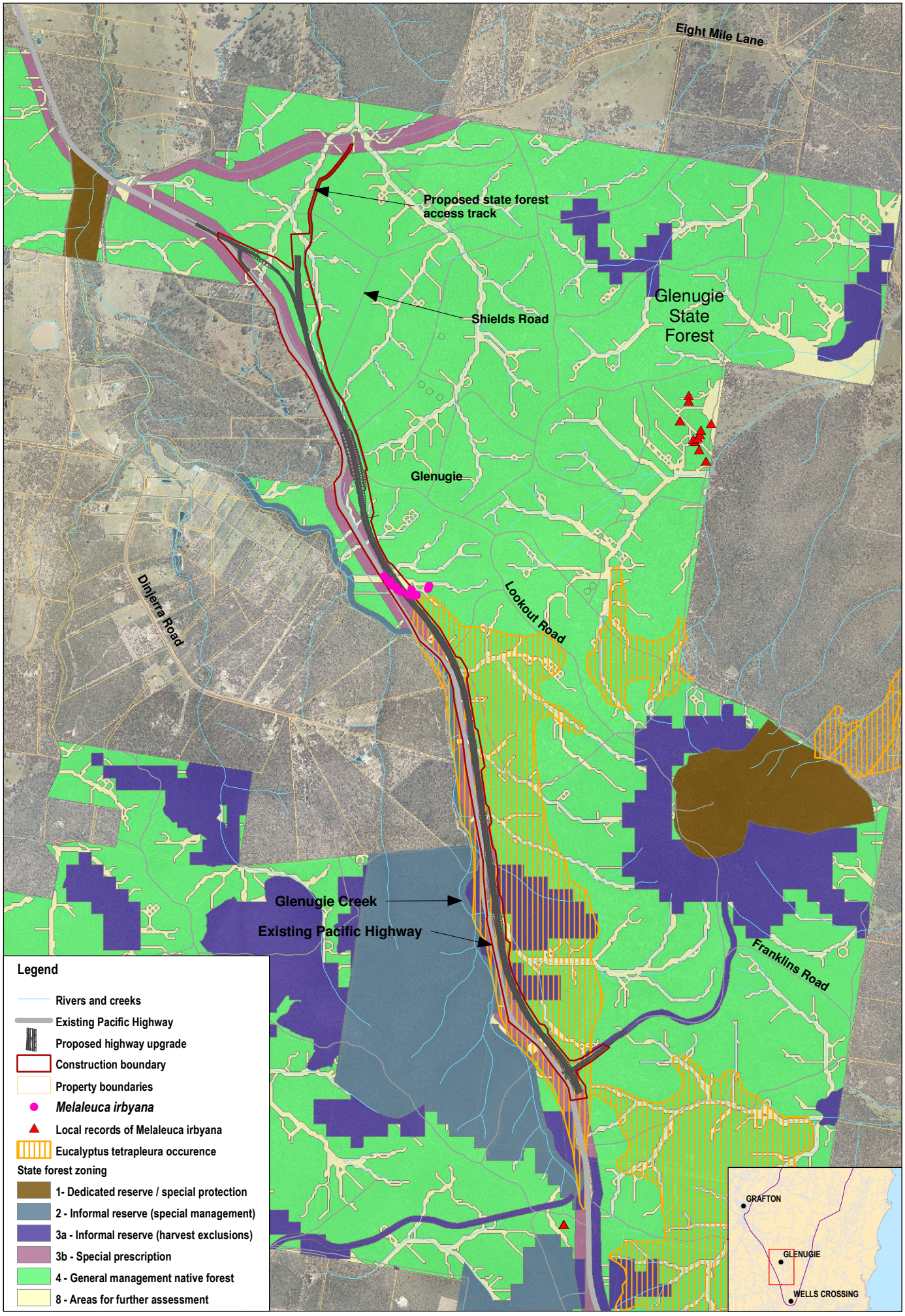
To address the residual impacts, the RTA will develop a biodiversity offset strategy in consultation with the DECC and Department of Planning. This strategy will aim to maintain or improve biodiversity values in the project area in the long-term.

6.4.2. Options for offsetting impacts

The results of the landscape assessment and targeted surveys for *Eucalyptus tetrapleura* in the region have been considered in determining offset options. Six potential options are presented for consideration in the preparation of any future offset strategy for the project. If possible, preference should be given to preserving the local provenance of *Eucalyptus tetrapleura* in proximity to the impact area:

- Two freehold properties located in the vicinity of the alignment were identified as containing a portion of the *Eucalyptus tetrapleura* population (c. 21,300 individuals). Both sites are strategically located adjacent to lands contained in the forestry Zone 1 (Special Protection) and such that there is scope to extend the reserved land or negotiate a conservation agreement. This option should also include securing a parcel of Glenugie State Forest located further west of the alignment and identified in the DPI database to comprise up to 100+ *Melaleuca irbyana* (refer to **Figure 6-2**).
- The most southern of the freehold properties discussed above comprises 9,084 *E.tetrapleura*. The preservation of these trees in addition to changing the zoning of the adjoining parcels of Glenugie State Forest that comprise *E. tetrapleura* and are currently zoned under forestry zone ‘General Management’ presents scope to preserve a further 20,000 *E. tetrapleura* within a forestry Special Management Zone with this option as well as habitat for threatened species. This option should also include securing a parcel of Glenugie State Forest located to the west of the alignment and known to comprise up to 100+ *Melaleuca irbyana* (refer to **Figure 6-2**).
- Investigate acquiring additional forestry land along the length of the proposed alignment through the identified *E. tetrapleura* population and preserve in a ‘road reserve’. An additional width of 250 m east of the alignment would be required in order to preserve an estimated 20,000 individuals (refer to **Figure 6-2**).

- Re-zone a portion of the forestry land located south of Franklins Road and containing a portion of the *Eucalyptus tetrapleura* population (i.e. 51,758 trees) to the equivalent around the 20,000 trees required to offset. This land is currently zoned for general management and therefore subject to logging. This land could be preserved in a formal conservation agreement or forestry special protection zone (refer to **Figure 6-2**).
- Investigate either freehold or forestry land outside of the Glenugie locality and comprising up to 20,000 *Eucalyptus tetrapleura*. This may require the acquisition of several small patches.
- Investigate either freehold or forestry land outside of the Glenugie locality that does not contain *Eucalyptus tetrapleura* but is equivalent in terms of ecological condition and size and may be suitable for planting of *Eucalyptus tetrapleura*.



Data Sources
Topodata: Streetworks, LPI 2008
Aerial: 2007

Figure 6-2: State forest zonings

0 1
A4 1:40,000 Kilometres

7. References

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Appendix A Potential subject species

KEY TO SYMBOLS USED IN APPENDIX A

Rare or Threatened Australian Plants (ROTAP) conservation codes (Briggs & Leigh 1996)

Distribution Category

1 Known by one collection only

2 Geographic range in Australia less than 100 km

3 Geographic range in Australia greater than 100 km

Conservation Status

X Presumed extinct, not collected or verified over the past 50 years

E Endangered, in serious risk of disappearing from the wild within 10-20 yrs if present land-use & other threats continue

V Vulnerable, not presently Endangered, but at risk over a longer period (20-50 years) of disappearing from the wild through continued depletion

R Rare but not currently threatened

K Poorly known taxon that is suspected but not definitely known to belong to one of the above categories. At present field distribution information is inadequate

C Reserved, indicates taxon has at least one population within a national park, other proclaimed conservation reserve or in an area otherwise dedicated to the protection of flora.

Size-class of all reserved populations

a 1000 plants or more known to occur within a conservation reserve(s)

i Less than 1000 plants are known to occur within a reserve(s)

- Reserved population size is not accurately known

t Total known population reserved

Commonwealth EPBC Act

Extinct in the wild

Critically endangered

Endangered (E)

Vulnerable (V)

NSW TSC Act

E1 Schedule 1 Part 1 Endangered Species

E2 Schedule 1 Part 2 Endangered Populations

E3 Schedule 1 Part 3 Endangered ecological communities

E4 Schedule 1 Part 4 Species Presumed Extinct

V Schedule 2 Vulnerable Species

NSW FM Act

E1 Schedule 4 Part 1 Endangered

E2 Schedule 4 Part 2 Endangered Population

E3 Schedule 4 Part 3 Endangered Communities

V Schedule 5 Vulnerable Species

A.1 Rare and threatened flora recorded in the study locality

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Acronychia littoralis Scented Acronychia	E	E	3ECi	Scented Acronychia is found between Fraser Island in Queensland and Port Macquarie on the north coast of NSW. Occurs in littoral rainforest on sand.	Yes	Very Low
Allocasuarina defungens Dwarf Heath Casuarina	E	E	2E	Found only in NSW from the Nabiac area, north-west of Forster, to Byron Bay on the NSW north coast. Grows mainly in tall heath on sand, but can also occur on clay soils and sandstone. The species also extends onto exposed nearby-coastal hills or headlands adjacent to sandplains.	No	Very Low
Amorphospermum whitei (Niemeyera whitei) Rusty Plum	-	V	-	Occurs in the coast and adjacent ranges of northern NSW from the Macleay River into southern Queensland. Its distributional stronghold is on the mid north coast around Coffs Harbour. Occurs in rainforest and the adjacent understorey of moist eucalypt forest.	Yes	Low
Angophora robur	V	V	2RC-	Occurs in a band from around Glenreagh, north-west of Coffs Harbour, to the Coaldale area north-west of Grafton, with an isolated occurrence farther west near Nymboida. It can be locally common. Dry open forest in sandy or skeletal soils on sandstone, or occasionally granite, with frequent outcrops of rock.	Yes	Low
Arthraxon hispidus Hairy Jointgrass	V	V	3VC-+	Occurs over a wide area in south-east Queensland, and on the northern tablelands and north coast of NSW, but is never common. Also found from Japan to central Eurasia. Moisture and shade-loving grass, found in or on the edges of rainforest and in wet eucalypt forest, often near creeks or swamps.	No	Low
Boronia hapalophylla Shannon Creek Boronia	-	E	-	This newly discovered species is currently only known from a small area near Shannon Creek, west of Coutts Crossing, in the Clarence Valley. It occurs in Chambigne Nature Reserve and on private property. The Shannon Creek Boronia occurs in dry woodland on sandstone hill slopes and ridge tops above Shannon Creek.	Yes	Low
Boronia umbellata Orara Boronia	V	V	2VC-	Found at only a few locations between Glenreagh and Lower Bucca, north of Coffs Harbour, but it is locally common in the restricted area where it occurs. This Boronia grows as an understorey shrub in and around gullies in wet open forest.	Yes	Moderate
Caesia parviflora var. minor	-	E	-	Found in damp places in open forest on sandstone. This variety occurs uncommonly in Tasmania, southern Victoria and south-east South Australia with an outlying population in NSW, in Barcoongere State Forest, between Grafton and Coffs Harbour. This variety may be more common than currently known, as Pale Grass-lilies are often not identified to variety level.	No	Moderate-High

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Centranthera cochinchinensis Swamp Foxglove	-	E	-	Occurs in northern Australia and south-east Asia and known from NSW north from Wooli. Uncommon in swampy areas and other moist sites.	No	Moderate
Corynocarpus rupestris Glenugie Karaka	V	V	2VC-t	This tree is known only from Glenugie Peak Flora Reserve, south-east of Grafton. Dry rainforest on steep basalt boulder slopes. Soil is scarce but relatively high in nutrients and very well-drained.	Yes	Low
Cryptostylis hunteriana	V	V	3VC-	Recorded from as far north as Gibraltar Range National Park south into Victoria around the coast as far as Orbost. It is known historically from a number of localities on the NSW south coast and has been observed in recent years at many sites between Batemans Bay and Nowra although it is uncommon at all sites. Also recorded at Nelson Bay, Wyee, Washpool National Park, Nowendoc State Forest, Ku-Ring-Gai Chase National Park, and Ben Boyd National Park. Does not appear to have well defined habitat preferences and is known from a range of communities, including swamp-heath and woodland. The larger populations typically occur in woodland dominated by Scribbly Gum (*Eucalyptus sclerophylla*), Silvertop Ash (*E. sieberi*), Red Bloodwood (*Corymbia gummifera*) and Black She-oak (*Allocasuarina littoralis*). Seems to prefer open areas in the understorey of this community and is often found in association with the Large Tongue Orchid (*C. subulata*) and the Tartan Tongue Orchid (*C. erecta*).	No	High
Cynanchum elegans White-flowered Wax Plant	E	E	3ECi	Occurs on the edge of dry rainforest vegetation. Other associated vegetation types include littoral rainforest; Coastal Tea-tree (*Leptospermum laevigatum*) – Coastal Banksia (*Banksia integrifolia subsp. integrifolia*) coastal scrub; Forest Red Gum (*Eucalyptus tereticornis*) aligned open forest and woodland; Spotted Gum (*Corymbia maculata*) aligned open forest and woodland; and Bracelet Honeymyrtle (*Melaleuca armillaris*) scrub to open scrub.	No	Moderate
Cyperus aquatilis Water Nutgrass	-	E	-	In NSW, known only from a few sites north from Grafton. Also occurs in Queensland, Northern Territory, Western Australia and New Guinea. Grows in ephemerally wet sites, such as roadside ditches and seepage areas from small cliffs, in sandstone areas.	No	Low
Eleocharis tetraquetra Square-stemmed Spike-rush	-	E	-	Thought to be extinct in NSW until it was rediscovered in 1997 at Boambee near Coffs Harbour. It has since been found in other north coast localities near Grafton and Murwillumbah. The species also occurs in south-east Queensland. Found in damp locations on stream edges and in and on the margins of freshwater swamps.	No	Moderate

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Eucalyptus glaucina Slaty Red Gum	V	V	3VCa	Found only on the north coast of NSW and in separate districts: near Casino where it can be locally common, and farther south, from Taree to Broke, west of Maitland. Grows in grassy woodland and dry eucalypt forest, on deep, moderately fertile and well-watered soils.	No	Moderate
Eucalyptus tetrapleura Square-fruited Ironbark	V	V	2VCa	Restricted to the coastal lowlands and foothills of northern NSW around Casino and Grafton. Dry or moist eucalypt forest on moderately fertile soil, often in low areas with poor drainage.	Yes	Very High
Grevillea masonii	E	E	2E	Occurs in only a few locations between Grafton and Casino in north-eastern NSW. Occurs on gravely loam soils and in sand in open eucalypt woodland.	No	Moderate
Grevillea quadricauda Four-tailed Grevillea	V	V	3VC-	In NSW it is found to the north-west of Whiporie in Mount Belmore State Forest and Mount Neville Nature Reserve, and at Tucabia east of Grafton. It also occurs near Toowoomba in south-east Queensland. Grows in gravely loam, in the understorey of dry eucalypt forest, usually along or near creeks.	No	Moderate
Hedyotis galioides (Oldenlandia galioides) Sweet False Galium	-	E	-	In north-east NSW, known from Whiporie State Forest south of Casino and one location in the Tweed district. Also occurs on the north-west plains of NSW and in Queensland, Northern Territory and Western Australia. Margins of seasonally inundated wetlands in paperbark swamps and Forest Red Gum *Eucalyptus tereticornis* woodlands.	No	Low
Leucopogon confertus Torrington Beard-heath	E	E	3E	Known only from an early record near Torrington on the New England Tablelands. Torrington Beard-heath possibly occurs in open forest and woodland on rocky granite areas.	Yes	Moderate
Lindsaea fraseri Fraser's Screw Fern	-	E	-	In NSW it is known only from two areas - near Hastings Point on the Tweed coast and in the Pillar Valley east of Grafton. Also occurs in far north and south-east Queensland. Poorly drained, infertile soils in swamp forest or open eucalypt forest, usually as part of a ferny understorey	No	Low
Lindsaea incisa Slender Screw Fern	-	E	-	In NSW it is known only from a few locations between Woombah and just south of Coffs Harbour. Also occurs in north and south-east Queensland. Dry eucalypt forest on sandstone and moist shrubby eucalypt forest on metasediments. It is usually found in waterlogged or poorly drained sites along creeks, where ferns, sedges and shrubs grow thickly.	Yes	Low
Marsdenia longiloba Slender Marsdenia	V	E	3RC-	Scattered sites on the north coast of NSW north from Barrington Tops. Also occurs in south-east Queensland. Subtropical and warm temperate rainforest, lowland moist eucalypt forest adjoining rainforest and, sometimes, in areas with rock outcrops	Yes	Moderate

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Maundia triglochinoides	-	V	-	Restricted to coastal NSW north from Wyong extending into southern Queensland. Former sites around Sydney are now extinct. Grows in swamps, creeks or shallow freshwater 30-60 centimetres m deep on heavy clay with low nutrients. Flowering occurs during warmer months and is associated with wetland species such as *Triglochin procerum*.	Yes	High
Melaleuca irbyana Weeping Paperbark	-	E	-	Found in only a few places in north-east NSW, including near Coraki, Casino and Coutts Crossing south of Grafton. Also occurs in near Ipswich south-east Queensland. Open eucalypt forest in poorly drained, usually clay, soils.	Yes	Very High
Melichrus hirsutus Hairy Melichrus	E	E	-	Restricted to a few locations near Grafton in north-east NSW. Dry eucalypt forest with a shrubby understorey on sandy infertile soils with rock outcrops.	Yes	Moderate
Olax angulata	V	V	2VCi	Restricted to a small area east of Grafton, near Minnie Water and Wooli, mainly in Yuraygir National Park and on nearby leasehold land. Locally common. Low-lying coastal heaths and heathy woodlands on sandy soils near swamps, often in association with Wallum Banksia (*Banksia aemula*).	No	Very Low
Parsonsia dorrigoensis Milky Silkpod	E	V	2VCi	Milky Silkpod is found only within NSW, with scattered populations in the north coast region between Kendall and Woolgoolga. Found in subtropical and warm-temperate rainforest, on rainforest margins, and in moist eucalypt forest up to 800 m, on brown clay soils. Flowers in summer. Little is known of the species' reproductive biology. Appears to be able to withstand, and maybe even favour, light to moderate physical disturbance.	No	Low
Persicaria elatior	V	V	3V	In northern NSW it is known from Raymond Terrace and the Grafton area. This species normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance.	No	Moderate
Phaius australis Southern Swamp Orchid	E	E	3VCa	Occurs in Queensland and north-east NSW as far south as Coffs Harbour. Historically, it extended farther south, to Port Macquarie. Swampy grassland or swampy forest including rainforest, eucalypt or paperbark forest, mostly in coastal areas.	No	Very Low
Phaius tankervilleae Lady Tankerville's Swamp Orchid	E	E	3VCa	Widespread, though seriously depleted, through Asia, New Guinea and Queensland and at least formerly, in north-east NSW. It may be extinct in north-east NSW. This orchid is found in swampy grassland or swampy forest, including rainforest, eucalypt and paperbark forest.	No	Very Low

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Polygala linariifolia Native Milkwort	-	E	-	North from Copeton Dam and the Warialda area to southern Queensland. Also found on the NSW north coast near Casino and Kyogle and in Western Australia. Sandy soils in dry eucalypt forest and woodland with a sparse understorey. The species has been recorded from the Inverell and Torrington districts growing in dark sandy loam on granite in shrubby forest of *Eucalyptus caleyi, Eucalyptus dealbata* and *Callitris*, and in yellow podsolic soil on granite in layered open forest. Associated species include *Eucalyptus trachyphloia, Eucalyptus sphaerocarpa, Angophora floribunda, Angophora leiocarpa, Lophostemon suaveolens, Allocasuarina torulosa* and *Wahlenbergia* species in the understorey. Flowers from spring to summer. Has been recorded as rare, sparse, occasional and common in populations.	No	Moderate
Prostanthera spinosa Spiny Mint-bush	-	V	-	Located within a small area to the north of Grafton. This NSW occurrence is very restricted and disjunct, separated by more than 1000 km from other occurrences in Victoria and South Australia, and may represent a distinct taxon. The confirmed records include locations within Fortis Creek National Park and Banyabba Nature Reserve. All known populations are within a linear range of 16-20 km. It grows in skeletal sandy soils of rocky areas.	Yes	Low
Quassia sp. Moonee Creek Monee Quassia	E	E	-	Scattered distribution from the Moonee Creek area north of Coffs Harbour to north-east of Grafton. Occurs in the shrubby layer below tall moist eucalypt forest and tall dry eucalypt forest, including forest edges, mostly at lower altitudes.	No	Low
Rutidosis heterogama	V	V	2VCa	Scattered coastal locations between Wyong and Evans Head, and on the New England Tablelands from Torrington and Ashford south to Wandsworth south-west of Glen Innes. Grows in heath on sandy soils and moist areas in open forest, and has been recorded along disturbed roadsides.	No	High
Taeniophyllum muelleri Minute Orchid	E	-	-	Grows on outer branches and branchlets of rainforest trees; coast and coastal ranges, from sea level to 250 m altitude, north from the Bellinger River.	No	Very Low
Thesium australe Austral Toadflax	V	V	3VCi +	Austral Toad-flax is found in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Often found in damp sites in association with Kangaroo Grass (*Themeda australis*). A root parasite that takes water and some nutrient from other plants, especially Kangaroo Grass.	Yes	Moderate-High

Threatened flora	Conservation status			Distribution and habitat requirements*	Records in the local area	Potential presence
	Cwlth	NSW	RoTAP			
Triplarina imbricata Creek Triplarina	E	E	2E	Found only in a few locations in the ranges south-west of Glenreagh and near Tabulam in north-east NSW. Along watercourses in low open forest with Water Gum (*Tristaniopsis laurina*).	No	Low
Tylophora woollsii Cryptic Forest Twiner	E	E	2E	Found from the NSW north coast and New England Tablelands to southern Queensland, but is very rare within that range. Known on the Tablelands from the Bald Rock and Boonoo Boonoo areas north of Tenterfield. 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 but sometimes as late as November. Thought to be wind-dispersed. Plants appear to persist as a network of stems under leaf litter when aerial stems are absent.	No	Moderate