12 Ecology

This chapter addresses the ecological impacts of the proposed upgrade. Both terrestrial and aquatic ecology are evaluated.

Environmental assessment requirement	Where addressed
> Consideration of threatened terrestrial and aquatic species, populations, ecological communities and/or critical habitat	Sections 12.3.2, 12.3.3, 12.3.4.
> Assessment of the following issues: native vegetation loss; weed infestation; habitat fragmentation; impacts to wildlife corridors including riparian corridors; impacts to groundwater-dependent communities, riparian and aquatic habitat	Sections 12.3.1, 12.3.5, 12.3.6, 12.3.8,12.3.9,
> Consideration of regional scale cumulative impacts and identify the significance of the impacts of the project in the context of the Pacific Highway Upgrade Program	Section 12.3.10

12.1 Assessment approach

The ecological assessment for the proposed upgrade involved terrestrial ecological studies by Biosis Research and aquatic ecological studies by The Ecology Lab. These assessments are documented in detail in *Working Paper 4 – Terrestrial flora and fauna assessment* and *Working Paper 5 – Aquatic ecology assessment.*

Terrestrial ecology

A number of terrestrial ecological investigations were carried out during the project, including:

> Targeted surveys for threatened species in the study area for the proposed upgrade on 14-18 November 2006.

> Verification of constraints mapping within the local area (as part of the route option development process) through site inspections on 1-2 and 14-15 November 2004, on 9-13 May 2005 and on 14-18 November 2005.

The term *study area* in relation to terrestrial ecology refers to the extent of the proposed works (including earthworks) plus 50 m (which allows for the majority of indirect effects on adjacent flora).

The terrestrial ecology study was conducted in accordance with the methodology employed for an assessment under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the Part 3A Guidelines for Threatened Species Assessment (DEC & DPI 2005). Additional fauna survey techniques (such as spotlighting and audio recordings of bat calls) were employed to target threatened species thought to occur in the area as well as to gather information on groups of species and to assist in the compilation of species lists.

Some plant species that occur in the local area are annuals (completing their life cycle within a single season) and are present only in the seed bank for much of the year. Other plant species are perennial, but are inconspicuous unless flowering. Similarly, some fauna may be seasonally absent from the study area. Some species that fall into these categories may not have been recorded during the current study.

However, threatened species that fall into these categories are still considered in the impact assessment, as the assessment is based on the presence or absence of suitable habitat for a threatened species, requiring only the presence of habitat, not individual records, for a threatened species to be considered further. The methodology employed for this assessment is sufficient to determine if the proposed upgrade would affect any threatened terrestrial species, populations or ecological communities. More detail on survey and assessment methodology is provided in *Working Paper 4 – Terrestrial flora and fauna report*.

Aquatic ecology

The aquatic ecology investigations included the following:

Habitat assessment of individual waterways on the basis of existing physical and ecological characteristics:

> Sampling and testing of water quality from each waterway.

> Sampling of each waterway for fish and mobile invertebrates (prawns and shrimps).

Field observations and investigations of aquatic habitats and water quality were made on three occasions:

> 30 November and the 2 December, 2004.

> 23 and 26 May 2005.

> 29 November to 1 December 2006.

The habitat value of aquatic habitats within the study area was classified according to NSW Department of Primary Industries' guidelines document, Aquatic Habitat Management and Fish Conservation (DPI 1999).

The term study area in relation to aquatic ecology refers to any watercourse or wetland (natural or artificial) occurring within 500m of the centreline of the proposed upgrade. The potential impact of the proposed upgrade on downstream watercourses and wetlands is also considered.

12.2 Existing ecological characteristics

12.2.1 Terrestrial vegetation communities

Vegetation identified in the study area falls into the following community classifications:

> Lowland rainforest.

> Camphor laurel.

> Plantation.

Community classifications are based on species composition and structure. Lowland rainforest is the only one of these communities that is naturally occurring. The lowland rainforest identified in the study area is regarded as fitting the definition of *lowland rainforest of the NSW North Coast and Sydney basin bioregions*, which is an endangered ecological community under the *Threatened Species Conservation Act 1995* (TSC Act).

Camphor laurel dominated vegetation was included despite the main species being a declared noxious weed, because it can perform some ecological function as fauna habitat and as a riparian buffer. Plantation refers to plantings of local, non-local native, and exotic species, but excludes macadamia plantations.

Fifteen individual vegetation patches were observed within the study area. These are shown on **Figure 12.1a-c** and described in **Table 12.1** below. The condition descriptions below are based on the level of weed intrusion and the representation of a natural structure and species composition.

Table 12.1 - Vegetation patches in the study area

Patch Number	Community type	Condition
1	Camphor laurel	poor
2	Lowland rainforest	poor
3	Lowland rainforest	poor to moderate
4	Lowland rainforest/Camphor laurel	poor to moderate
5	Lowland rainforest	poor
6	Lowland rainforest	poor
7	Lowland rainforest	poor
8	Plantation	poor
9	Camphor laurel	poor
10	Lowland rainforest	moderate
11	Lowland rainforest	poor
12	Camphor laurel	poor
13	Camphor laurel/Lowland rainforest	poor
14	Camphor laurel	poor
15	Lowland rainforest	poor

12.2.2 Terrestrial flora species

A total of 195 species of vascular plant were recorded from the study area, comprising 139 (71 percent) indigenous species and 56 (29 percent) introduced species.

Forty-nine threatened plant species listed under the TSC Act and/or the Environment *Protection and Biodiversity Conservation Act 1999* (EPBC Act), have been recorded or have potential habitat within 10 km of the study area (*DECC Atlas of NSW Wildlife* and the Federal Department of Environment, Water, Heritage and the Arts EPBC Online Database). Four threatened species listed under the TSC Act and EPBC Act have been previously recorded within the study area with the records confirmed during field surveys for the proposed upgrade, *Diploglottis campbellii, Macadamia tetraphylla, Syzygium moorei and Tinospora tinosporoides*. Two species listed as rare or threatened Australian plants (ROTAP) by Briggs and Leigh (1995), but not listed under the TSC Act or EPBC Act were recorded in the study area (*Archidendron muellerianum and Quassia sp. 'Mt Nardi'*).

12.2.3 Terrestrial fauna habitats

Suitability, size and configuration of vertebrate fauna habitats broadly correlate to the structure, connectivity and quality of local and regional vegetation types. Generally, these habitats can be categorised as:

> Rainforest.
> Camphor laurel.
> Plantations.
> Riparian (including rivers, creeks, drainage lines and wetlands).
> Cleared areas.

Finer scale habitat features in and near the study area include foraging resources, tree hollows, hollow logs, dams, temporary ponds and soaks. The habitat value of each is discussed in the following Figures.

Rainforest

Rainforest habitats provide a wide range of food and shelter for vertebrate fauna. This habitat has been highly disturbed and is restricted to small isolated patches of rainforest remnants within the study area which nonetheless have a refuge and other habitat functions for a range of species. This habitat correlates to lowland rainforest discussed in **Section 12.2.1** above.

Typical tree species in this habitat include figs, palms, silky oak, black bean and brush cherry, and supply food resources for a range of species, particularly birds and mammals. Mature trees which have the potential to support hollows (formed in stags, mature and/or senescent trees) are very limited.

The shrub vegetation and understorey is typically sparse reaching a maximum height of approximately 2 m and 1 m respectively. Abundant habitat is present with a scattered layer of ferns, vines and grasses covering a thick layer of leaf litter, bark and fallen logs. Many invertebrates and amphibians rely on this moisture-retaining habitat to over-winter or as refuge during periods of drought. Similarly, many reptiles rely on ground litter and debris for shelter and foraging.

All examples of this habitat in the study area have been previously disturbed and are subject to ongoing direct and indirect disturbance. The rainforest habitat is considered to have a moderate habitat value based on the ground flora containing a high number of indigenous species; the ground, log and litter layer being largely intact; and a large variety of habitat and resources being available for a range of native fauna.

Examples of threatened fauna that may utilise these habitats include rose-crowned fruit dove *P. regina*, masked owl, grey-headed flying fox and microchiropteran bats.

Camphor laurel

The study area contains a number of isolated patches of vegetation dominated by camphor laurel with *Pittosporum undulatum* and *Lantana camara*. The shrub layer and understorey are also dominated by camphor laurel saplings. Although this habitat is not generally as diverse as native forest, it can provide habitat for a range of fauna. Camphor laurel provides an important winter food source for fruit-eating fauna such as the rose-crowned fruit dove, topknot pigeon *Lopholaimus antarcticus* and white-headed fruit dove *Columba leucomela*. Habitat features such as logs, leaf litter, ferns and vines also provide shelter and foraging habitat for a range of native fauna including birds and reptiles.

Figure 12.1a - Vegetation

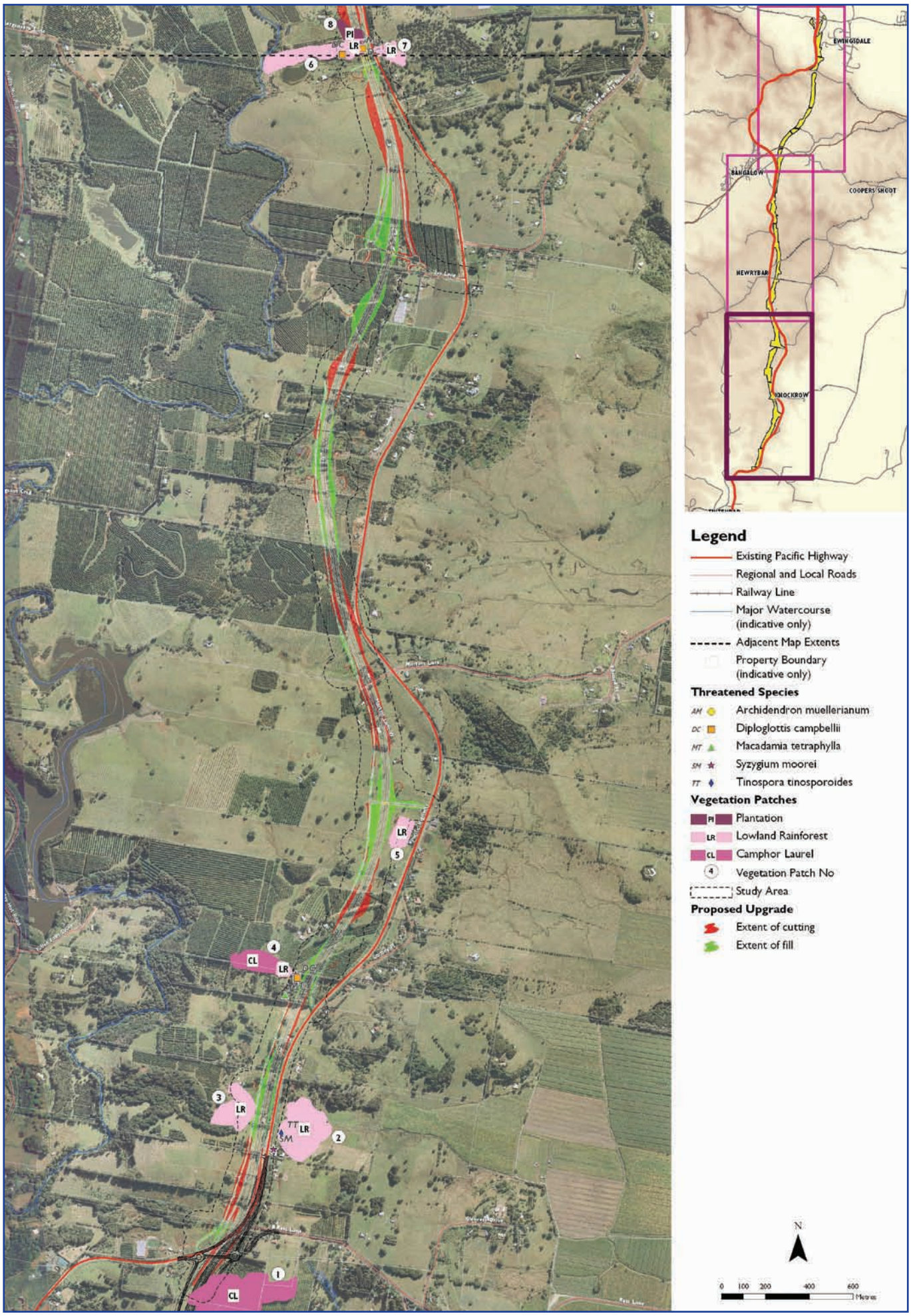


Figure 12.1b - Vegetation

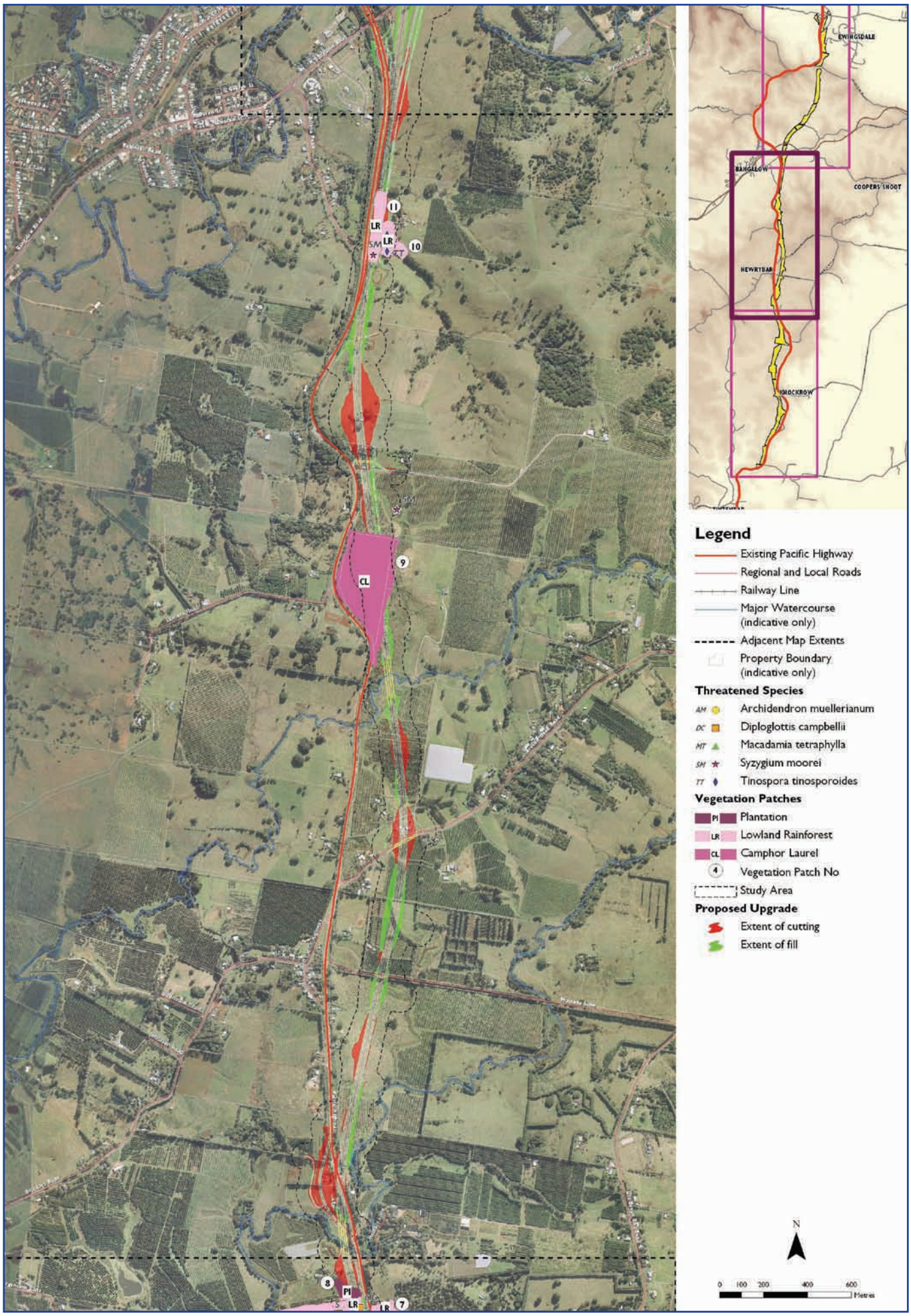
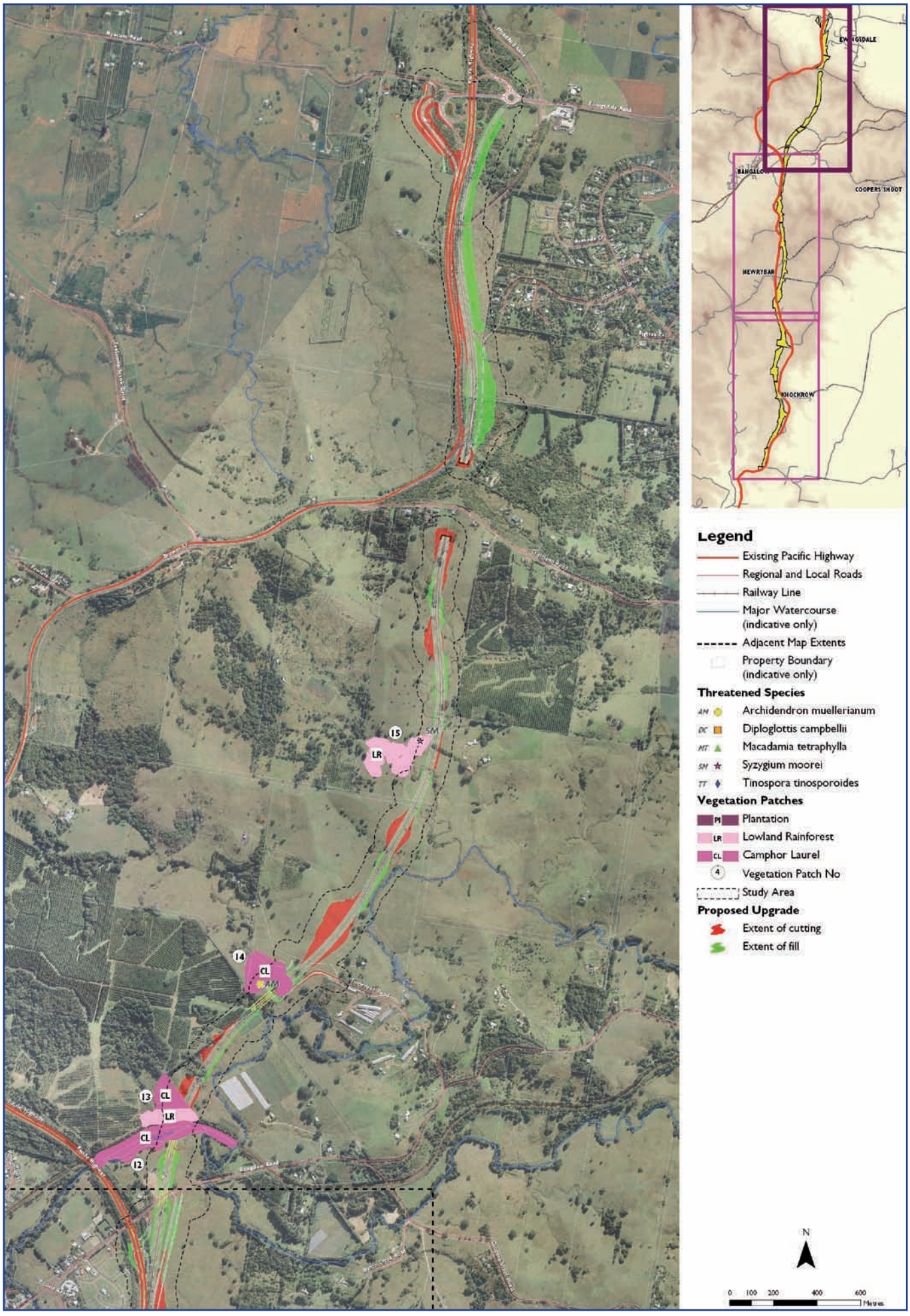


Figure 12.1c - Vegetation



Camphor laurel habitat is considered to have a moderate habitat value, with the ground flora containing a low number of indigenous species; plant communities being fragmented; and ground, log and litter layer being highly disturbed.

This habitat provides potential foraging habitat for the threatened species wompoo fruit dove *Ptilinopus magnificu*s, rose-crowned fruit dove *Ptilinopus regina*, superb fruit dove *P.superbus*, and grey-headed flying fox.

Riparian

These riparian habitats are discussed in terms of habitat for terrestrial fauna only. See **Section 12.2.5** for a description of habitat for aquatic fauna.

Wet depressions (heath/sedgeland), creeks, drainage lines and farm dams provide optimal habitat for a range of vertebrate (amphibians, reptiles and small ground-dwelling mammals) and invertebrate species. These areas occur in various forms throughout the study area.

Larger creeks within the study area, such as Emigrant and Byron creeks provide habitat and resources for a range of species. The creek environment includes in-stream habitats, riverbanks, riparian vegetation and associated swamps. These habitats have a range of characteristics making them attractive to fauna such as the common eastern froglet *Crinia signifera* and large-footed myotis.

The creeklines within the study area have been previously disturbed due to agricultural, rural and residential development and associated infrastructure. They generally consist of only a narrow strip (10-20 m) of riparian vegetation through an otherwise agricultural landscape. These habitats within the study area are considered to have moderate habitat value.

Cleared areas

Some sections within and near the study area have been cleared for a range of uses including agriculture, residential properties and infrastructure. Despite these changes, some native species, such as Latham's snipe *Gallinago hardwickii*, may occur within disturbed vegetation and microhabitat components of these areas. However, generally these areas provide few habitat opportunities for native fauna. Species more likely to inhabit these areas include introduced and domestic animals and common native species tolerant of disturbance or favouring edge/ecotone habitat.

Cleared areas are considered to have low habitat value, with the ground flora containing a low number of indigenous species; plant communities being fragmented; the ground, log and litter layer being highly disturbed; and few resources available for native fauna.

Plantations

A number of pine and eucalypt plantations occur within the study area. Although these areas generally provide few opportunities for native fauna, they do provide foraging habitat for birds and bats, including the grey-headed flying fox which is listed as vulnerable on Schedule 2 of the TSC Act.

Plantations are considered to have low habitat value, with the ground flora containing a low number of indigenous species; ground, log and litter layer being highly disturbed; and few resources available for native fauna.

12.2.4 Wildlife corridors and habitat connectivity

A number of wildlife corridors have been identified by Department of Environment and Climate Change (DECC) and Byron Shire Council in the general Byron Bay/Bangalow area (**Figure 12.2**). The identification of these corridors is based on a regional scale representation of potential habitat and linking habitat for species and species assemblages. One of these corridors crosses the study area along the St Helena ridgeline and connects coastal ecosystems south and west of Byron Bay, to upland ecosystems west and north-west of Bangalow. The quality and extent of wildlife habitat within this corridor is relatively low and its designation as a wildlife corridor appears to be more related to its future potential with appropriate management than its current functionality.

On a more local scale, terrestrial wildlife would be expected to move along some of the creek corridors where there is a degree of riparian vegetation occurring. Emigrant Creek and Byron Creek are likely to be the most significant of these.

It should be noted that due to the large amount of clearing that has taken place in the landscape, even small patches of vegetation can be considered to be important habitat value to some fauna species. The isolated patches described in **Section 12.2.1** along with other vegetation patches in close proximity to the proposed upgrade, provide habitat stepping stones for more mobile species.

Terrestrial fauna species

Sixty-eight species of vertebrate were recorded from the study area including five amphibians, two reptiles, seven mammals and fifty-four birds. All species recorded are native apart from the introduced cane toad. Seven species listed under the EPBC Act, the TSC Act or both were recorded. These are listed in **Table 12.2** below.

Table 12.2 - Significant fauna species recorded during surveys of the study area

Latin name	Common name	EPBC Act status	TSC Act status
Ardea ibis	Cattle egret	Migratory	
Monarcha melanopsis	Black-faced monarch	Migratory	
Tyto novaehollandiae	Masked owl		Vulnerable
Pteropus alecto	Black flying fox		Vulnerable
Pteropus poliocephalus	Grey-headed flying fox	Vulnerable	Vulnerable
Miniopterus australis	Little bent-wing bat		Vulnerable
Myotis macropus*	Large-footed myotis		Vulnerable

* This species was previously grouped with Myotis adversus

An additional 58 species listed under the EPBC and TSC Acts have been previously recorded within 10 km of the study area (based on a search of the Atlas of NSW Wildlife (DECC 2008)) and have potential habitat within the study area. These are shown in **Table 12.3.**

Figure 12.2 - Previously identified wildlife corridors

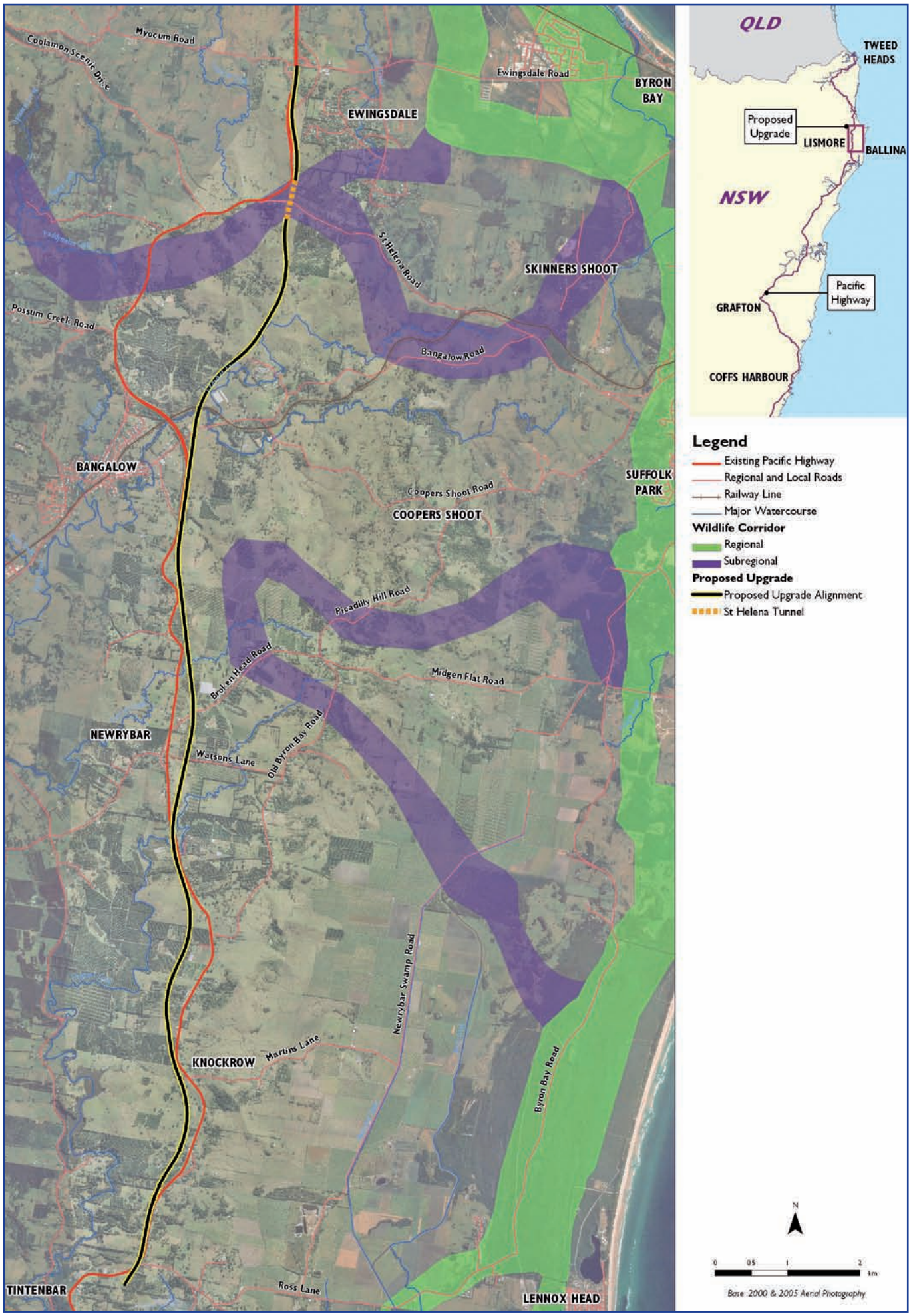


Table 12.3 - Threatened animal species with known/potential habitat likely to be impacted by the proposed upgrade

Scientific Name	Common Name	TSC Act	EPBC Act
Amphibians			
Assa darlingtoni	Pouched Frog	V	-
Crinia tinnula	Wallum Froglet	V	
Litoria aurea	Green and Golden Bell Frog	E1	V
Litoria olongburensis	Olongburra Frog	V	V
Birds			
Amaurornis olivaceus	Bush-hen	V	-
Anseranas semipalmata	Magpie Goose	V	-
Botaurus poiciloptilus	Australasian Bittern	V	-
Burhinus grallarius	Bush Stone-curlew	E1	-
Calyptorhynchus banksii	Red-tailed Black-cockatoo	V	E
Calyptorhynchus lathami	Glossy Black-cockatoo	V	E
Coracina lineata	Barred Cuckoo-shrike	V	-
Cyclopsitta diophthalma	Coxen's (Double-eyed) Fig-Parrot	E1	E
Dromaius novaehollandiae	Emu	E2	-
Ephippiorhynchus asiaticus	Black-necked Stork	E1	-
Erythrotriorchis radiatus	Red Goshawk	E1	VM
Gallinago hardwickii	Latham's Snipe	-	M
Grus rubicunda	Brolga	V	M
Haliaeetus leucogaster	White-bellied Sea-eagle		M
Hirundapus caudacutus	White-throated Needletail		M
Irediparra gallinacean	Comb-crested Jacana	V	-
Ixobrychus flavicollis	Black Bittern	V	-
Lathamus discolor	Swift Parrot	E1	EM
Lichenostomus fasciogularis	Mangrove Honeyeater	V	-
Lophoictinia isura	Square-tailed Kite	V	M
Monarcha leucotis	White-eared Monarch	V	-
Monarcha trivirgatus	Spectacled Monarch	-	M
Myiagra cyanoleuca	Satin Flycatcher	-	M
Pandion haliaetus	Osprey	V	
Pezoporus wallicus	Ground Parrot	V	
Podargus ocellatus	Marbled Frogmouth	V	-
Poephila cincta	Black-throated Finch	E1	V
Pomatostomus temporalis temporalis	Grey-crowned Babbler	V	-
Ptilinopus magnificus	Wompoo Fruit-dove	V	-
Ptilinopus regina	Rose-crowned Fruit-dove	V	-
Ptilinopus superbus	Superb Fruit-dove	V	-
Puffinus carneipes	Flesh-footed Shearwater	V	M
Rhipidura rufifrons	Rufous Fantail	-	M
Rostratula benghalensis	Painted Snipe	V	VM
Stagonopleura guttata	Diamond Firetail	V	

Table 12.3 (cont)

Scientific Name	Common Name	TSC Act	EPBC Act
Stictonetta naevosa	Freckled Duck	V	M
Todiramphus chloris	Collared Kingfisher	V	-
Turnix maculosa	Red-backed Button-quail	V	
Turnix melanogaster	Black-breasted Button-quail	E1	V
Tyto capensis	Grass Owl	V	-
Tyto tenebricosa	Sooty Owl	V	-
Xanthomyza phrygia	Regent Honeyeater	E1	E
Mammals			
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Dasyurus maculatus	Spotted-tailed Quoll	V	E
Miniopterus schreibersii	Eastern Bent-wing Bat	V	-
Nyctimene robinson	Eastern Tube-nosed Bat	V	
Nyctophilus bifax	Eastern Long-eared Bat	V	V
Phascolarctos cinereus	Koala	V	-
Planigale maculata	Common Planigale	V	-
Potorous tridactylus	Long-nosed Potoroo	V	V
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-
Syconycteris australis	Common Blossom-bat	V	-
Reptiles			
Coeranoscincucs reticulatus	Three-toed Snake-tooth Skink	V	V
Invertebrates			
Thersites michellae	Mitchell's Rainforest Snail	E1	Z

E = endangered species (EPBC Act)

E1 = endangered species (TSC Act)

E2 = endangered population (TSC Act)

V = vulnerable species (TSC and EPBC Acts)

M = migratory species (EPBC Act)

Z = critically endangered species (EPBC Act)

12.2.5 Aquatic habitats

The habitat value of aquatic habitats within the study area was evaluated on the basis of field investigations of the named creeks. A summary of the habitat value of each of these habitats is shown in **Table 12.4**.

Table 12.4 - Aquatic habitat value

Aquatic Habitat	Habitat Value *
Tributary of Emigrant Creek	Class 3 – minimal fish habitat
Emigrant Creek (downstream of dam)	Class 2 – moderate fish habitat
Emigrant Creek (0-2 km upstream of dam)	Class 1 – major fish habitat
Emigrant Creek (immediately downstream of existing highway crossing)	Class 2 – moderate fish habitat
Emigrant Creek (upper reaches)	Class 3 and 4 - minimal and unlikely fish habitat
Skinners Creek	Class 3 and 4 - minimal and unlikely fish habitat
Byron Creek	Class 2 – moderate fish habitat
Tinderbox Creek and tributaries	Class 2 and 3 - moderate and minimal fish habitat

* Habitat value is based on NSW Department of Primary Industries' guidelines document, ***Aquatic Habitat Management and Fish Conservation.***

Higher fish habitat values are given to those creeks with a relatively high water quality and where the creek morphology is conducive to fish habitat. The Class 1 rating for Emigrant the area immediately upstream of Emigrant Creek dam is largely due to its relatively large volume, which provides good habitat for a range of fish species.

12.2.6 Threatened aquatic species

The *Fisheries Management 1994 (FM Act)* identifies two threatened freshwater species whose ranges potentially include the watercourses traversed by the proposed upgrade. These species are the endangered eastern freshwater cod (*Maccullochella ikei*) and oxleyan pygmy perch (*Nannoperca oxleyana*). A search of the NSW Fisheries *fishfiles* database found records for both of these species within the Richmond River system, however, none of these records were within the Emigrant Creek, Skinners Creek, Tinderbox Creek or Byron Creek catchments.

Given that eastern freshwater cod has only been recorded well downstream and in larger watercourses than exist in the vicinity of the proposed upgrade, it is considered unlikely that suitable habitat occurs.

The oxleyan pygmy perch only occurs in low-lying Banksia dominated ecosystems. This habitat does not occur in the vicinity of the proposed upgrade.

Emigrant Creek downstream of the existing highway crossing. This part of Emigrant Creek has been identified as having moderate fish habitat value.

12.3 Impacts on ecology

12.3.1 Loss of terrestrial vegetation and fauna habitat

Table 12.5 shows the area of each plant community recorded in the study area that would be affected by the proposed upgrade. Direct impact refers to vegetation clearance. Indirect impacts are calculated by buffering the direct impact area by 50 m, based on a 50 m average extent of edge effects described by Biosis Research (2000) and Bali (2005).

Table 12.5 - Area of each plant community affected by the proposed upgrade

Plant community	Affected area (ha)	
	Direct	Indirect
Lowland Rainforest	2.0	3.6
Camphor Laurel	5.7	9.5
Plantation	2.7	0.5
Total	**10.4**	**13.6**

Small fragmented patches of native vegetation would be affected by the proposed upgrade. The condition of the vegetation that would be affected is generally poor, due to previous direct disturbance and the influence of edge effects that results from its fragmentation. This vegetation does have some habitat value however, particularly given the clearance that has previously occurred in the landscape.

A large proportion of the vegetation occurs as the result of planting and does not have the potential to become self-sustaining. The majority of vegetation to be removed is from patches dominated by camphor laurel, which, while performing some wildlife habitat function, is a declared noxious weed in this area.

12.3.2 Loss of threatened ecological communities and critical habitat

There would be a potential direct loss of 2.0 ha of lowland rainforest (listed as an endangered ecological community under the TSC Act). Existing edge effects on adjacent lowland rainforest may also be exacerbated by the proposed upgrade. There is estimated to be 776 ha of lowland rainforest within 10 km of the study area. The proposed upgrade would result in the direct loss of 0.26 percent of this.No critical habitat listed under the TSC Act or the EPBC Act would be affected by the proposed upgrade.

12.3.3 Loss of threatened plant species

Four threatened plant species previously recorded and/or recorded during surveys would be directly or indirectly affected by the proposed upgrade. These are described following and shown in **Figures 12.1a, b and c.**

Diploglottis campbellii

Diploglottis campbellii is listed as endangered under both the TSC and EPBC Acts. The following individual specimens have been recorded in the project area:

> Two (apparently planted) specimens in vegetation patch 6.
> One specimen immediately south-east of vegetation patch 4.

Macadamia tetraphylla

Macadamia tetraphylla is listed as vulnerable under both the TSC and EPBC Acts. Hybrids of the species occurring in commercial plantations are not included in this assessment. The following individual specimen has been recorded in the study area:

> One planted specimen in a garden landscape near vegetation patch 4.

Syzygium moorei

Syzygium moorei is listed as vulnerable under both the TSC and EPBC Acts. The following individual specimens have been recorded in the study area:

> One record in vegetation patch 15, supporting 15 mature trees.
> One specimen in vegetation patch 11.
> One specimen to the north of vegetation patch 9 on the edge of the study area.
> One specimen (likely to have been planted) in vegetation patch 6.
> One planted specimen in a garden landscape south-west of vegetation patch 2.

Tinospora tinosporoides

Tinospora tinosporoides is listed as vulnerable under both the TSC and EPBC Acts. The following individual specimens have been recorded in the study area:

> Two specimens in vegetation patch 10.
> One specimen in vegetation patch 2.

12.3.4 Loss of significant fauna species

A detailed evaluation of potential impact on each of the recorded and potentially occurring significant fauna species is included in *Working Paper 4 – Terrestrial flora and fauna assessment.* The evaluation identifies no significant impacts of the proposed upgrade on any of these species. This is primarily due to the small amount of habitat that would be removed by the project, combined with the relatively low habitat value of the majority of this habitat. Many of the species with actual or potential habitat in the study area (including all of the species recorded in survey undertaken for the proposed upgrade) are highly mobile and not dependent on these small habitat fragments for their survival.

Stand of the threatened species Syzygium moorei in vegetation patch 15.

12.3.5 Habitat fragmentation and barrier effects

The study area has been highly disturbed and contains a number of isolated patches of remnant vegetation. The proposed upgrade generally follows the path of the existing Pacific Highway, thereby minimising further fragmentation of habitats and barrier effects. The proposed upgrade is unlikely to increase the impact of fragmentation on threatened species and endangered ecological communities in the local area given the high degree of fragmentation in the existing landscape.

The proposed upgrade crosses a previously identified sub-regional wildlife corridor in the northern section of the study area. However, the road would be tunnelled through St Helena ridge, thereby minimising fragmentation within the identified corridor and not hindering future efforts to improve the functionality of the corridor.

12.3.6 Edge effects and weed infestation

Edge effects are zones of changed environmental conditions (such as altered light levels, wind speed, temperature) occurring along the edges of habitat fragments. These new environmental conditions along the edges can promote the growth of different vegetation types (including weeds) and allow invasion by pest animals specialising in edge habitats. Edge zones can be subject to higher levels of predation by introduced mammalian predators and native avian predators (Berry 2002). This new zone of habitat inside the edge of a fragment can also exacerbate barrier effects.

Using the estimate of edge effects of 50 m proposed by Biosis Research (2000), the proposed upgrade would affect 3.6 ha of native vegetation through edge effects. An additional 10 ha of non-native vegetation would also be affected by edge effects (**Table 12.5**). The proposed upgrade would not create any new edge effects, as the affected patches are small and isolated and already heavily edge affected by other existing uses. It may however increase the magnitude of the existing edge effects.

12.3.7 Mortality

Fauna injury or death can occur as a result of highway construction and operation in two ways:

- *During the break-out phase of construction (when vegetation is removed to expose a natural earth substrate*). Habitat clearance may result in the injury or death of resident or visiting fauna. Some species can more readily evade injury by flying (birds) or 'running' away (such as the larger mammals). Many species, however, are unlikely to move quickly enough to avoid the clearing activities. For example, many nocturnal species (possums, gliders, bats) shelter during the day and smaller ground-dwelling species, such as lizards and snakes, are unable to move rapidly and over large distances.
- *Road kills*. Mortality due to road kill during operation has the potential to affect local fauna species at the sub-population level. In general, rates of road kill mortality are likely to be directly proportional to the distance of native vegetation/fauna habitat crossed by the highway (Forman et al. 2003). However, other factors such as the design of the road (such as height in relation to surrounding ground level, presence of walls and fences, fauna underpasses) also influence road kill mortality. As there is a small amount of habitat for species vulnerable to road kill mortality, roadkill would not be not anticipated to be a major cause of mortality on local populations of wildlife.

12.3.8 Aquatic disturbance, changed hydrology and fish passage

The watercourses along the proposed upgrade are small creeks or drainage lines. Crossing watercourses of this nature would cause little to no impact on aquatic habitats, assuming no in-stream structures are required. New bridges would be installed where the proposed upgrade crosses a tributary of Emigrant Creek, Emigrant Creek, Skinners Creek, Byron Creek and a tributary of Tinderbox Creek.

The proposed upgrade includes the diversion of Tinderbox Creek or its small tributaries in three locations to avoid multiple creek crossings over short distances. The diverted sections of the creek would be created to mimic the creek under the footprint of the proposed upgrade and would not cause significant reductions in habitat availability or water quality.

Potential impacts to aquatic ecology are summarised in **Table 12.6.**

Table 12.6 - Aquatic ecology impact summary

Catchment/Watercourse	Potential Impact
Emigrant Creek/Unnamed tributary of Emigrant Creek	> Highway batter would be located approximately 21 m from the creek, with a distance of 17 m from the edge of the cleared area, potential for run-off into creek.
Emigrant Creek/Drainage Lines between Carney Place and Ivy Lane	> Headwaters of minor creek diverted via box culvert, loss of natural creek habitat (app 160 m).
Emigrant Creek/ Martins Lane to Tributary of Emigrant Creek	> Diversion of altered creek line near Palm Springs Fish Hatchery, reduction in natural and created fish habitat as creek is diverted through culverts.
Emigrant Creek/Tributary of Emigrant Creek	> New bridge crossing would shade approximately 30 m of creek line.
Emigrant Creek/Emigrant Creek	> New bridge crossing to west of existing Pacific Highway bridge would shade 60 m of creek line.
Skinners Creek/ Tributary of Skinners Creek	> New bridge crossing upstream of existing Pacific Highway bridge would shade 35 m of creek line; reduction in natural habitats where creek is diverted beneath upgrade footprint via culverts
Byron Creek/Byron Creek	> Reduction in natural habitats where creek is diverted beneath upgrade footprint via culverts; new bridge crossing upstream east of the existing would shade about 43 m of creek line.
Tinderbox Creek/Tributary of Tinderbox Creek and Tinderbox Creek	> New bridge crossing would shade about 40 m of creek line; reductions in natural creek habitat on the order of 140 m (total) due to multiple diversions of creek line over meandering reach of creek
Simpson Creek/Tributaries of Simpsons Creek	> Reduction in natural creek habitat due to installation of culverts on minor creek lines

12.3.9 Groundwater dependent communities

The Bureau of Rural Sciences Australia (Brodie and Green 2002) identified and mapped the groundwater dependant ecosystems on the Alstonville Plateau, which are described as:

Wetlands – aquatic communities and fringing vegetation dependent on groundwater fed lakes and wetlands. These are lands permanently or temporarily under water or water logged, and include groundwater springs and seepage areas. There are no groundwater dependant wetlands in the study area.

River base flow systems – aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow. Groundwater may be a significant contributor to flows in coastal streams supporting riparian forests, "sedgelands" and grasslands, as well as in-stream flora and fauna.

Terrestrial vegetation – vegetation communities and dependent fauna that have seasonal or episodic dependence on groundwater. These include trees and shrubs that require the water table to be at least episodically or periodically within their root zone.

Native plant communities recorded within the study area that may be groundwater dependant include rainforest and riparian vegetation.

The outcome of predictive modelling described in *Working Paper 3 – Groundwater assessment*, suggests that impacts to groundwater dependant ecosystems in the hyporheic zone (the zone where groundwater and stream water mixes) are likely in the case of cuts which penetrate into the water table zone upgradient of springs and creeks.

The in-stream ecology of some small drainage lines would potentially be impacted as a result of localised groundwater changes created by some of the larger proposed cuts (as described in **Table 11.2**). Proposed management measures are likely to restrict any impacts to negligible or highly localised levels. None of the identified patches of terrestrial vegetation described in **Section 12.2.1** would be in the area potentially impacted by these cuts.

12.3.10 Regional scale cumulative impacts

The proposed upgrade occurs in a highly developed landscape, dominated by rural development. Consequently, much of the native vegetation of the local area has been cleared and the remnants are small, isolated and fragmented. Accordingly, the proposed upgrade in itself would have a relatively low impact.

The overall biodiversity impacts of the entire Pacific Highway Upgrade Program are greater than those assessed in association with the Tintenbar to Ewingsdale upgrade. Sections of the highway are at different stages of planning and development, with some sections already upgraded and others proposed for upgrade. The cumulative impacts of the entire Pacific Highway Upgrade Program would include a greater extent of clearing of native vegetation and habitats, including endangered ecological communities and threatened species habitat, as well as further fragmentation of habitat.

Table 12.7 details the direct vegetation removal associated with the 13 Pacific Highway Upgrade Program projects that have been declared critical infrastructure by the Minister for Planning under Section 75B(1) of the *Environmental Planning and Assessment Act 1979*. Twelve of the 13 projects (the exception is F3 to Raymond Terrace) are located within the

North Coast bioregion (IBRA 5-1, Thackway & Cresswell 1995). In relation to the Pacific Highway Upgrade Program, the proposed upgrade represents 4.2 percent of the total length of the Pacific Highway to be upgraded, 0.7 percent of the total vegetation to be removed (note: for the proposed upgrade, this includes non-native treed vegetation) and approximately 0.45 percent of the likely extent of endangered ecological communities to be removed. However, it should be noted that the final route of some of these projects have not yet been finalised and the total extent of vegetation clearing may change as the projects develop. For projects at earlier stages of planning, the clearing estimates are more likely to be revised downward as the figures provided reflect the entire corridor width rather than the extent of pavement and earthworks.

Table 12.7 - Regional scale cumulative ecological impacts

Project name	Project status	Project length (km)	Likely vegetation disturbance (ha)	Likely endangered ecological community disturbance (ha)
Banora Point	Environmental assessment submitted for approval	2.5	8	4
Tintenbar to Ewingsdale	Environmental assessment commenced	17	10	2
Woodburn to Ballina	Concept design selected	36	66	52
Iluka Road to Woodburn	Concept design selected	35	117	31
Wells Crossing to Iluka Road	Preferred route selected	71	410	88
Woolgoolga to Wells Crossing	Preferred route selected	27	207	33
Sapphire to Woolgoolga upgrade	Environmental assessment submitted for approval	25	83	18
Coffs Harbour Bypass	Concept design included in LEP	55	Not yet available	Not yet available
Macksville to Urunga	Environmental assessment commenced	3	Not stated	Not stated
Warrell Creek to Urunga	Environmental assessment commenced	45	236	82
Kempsey to Eungai	Environmental assessment submitted for approval	40	258	65
Oxley Highway to Kempsey	Environmental assessment commenced	37	229	66
F3 to Raymond Terrace	Preferred route selected	14	Not yet available	Not yet available

12.4 Management of impacts

12.4.1 Loss of terrestrial vegetation and fauna habitat

Measures proposed to minimise the loss of terrestrial vegetation and fauna habitat include:

> Vegetation clearing would be restricted to those areas where it is absolutely necessary.

> Where clearing does occur, the area would be fenced with highly visible temporary fencing or flagging tape to ensure that clearing does not extend beyond the area necessary.

> Clearing of vegetation would comply with the RTA Pacific Highway Office requirements for fauna rescue associated with roadworks.

> Where suitable, nest boxes would be used to replace any removed tree hollows. Such a program would be developed in consultation with DECC.

> Restoration, regeneration and rehabilitation of areas of native vegetation would occur where it remains within the proposed road reserve. Riparian restoration would be undertaken where creeklines occur on land that is acquired as part of the proposed upgrade, but that would be outside the construction footprint.

> Vegetation management measures would be integrated with the landscape plan for the project.

12.4.2 Loss of threatened ecological communities

The measures listed in **Section 12.4.1** generally apply to the management of impacts on lowland rainforest.

In addition to project specific measures, any compensation over and above (or instead of) that rehabilitation would be negotiated as part of a compensatory habitat package which has been agreed previously with the DECC, covering all Pacific Highway proposals in the area between Ballina and the Queensland border (known as "section 5"). This sectional approach provides for a larger and more effectively manageable area of compensatory habitat, suitable for use as an offset for the Tintenbar to Ewingsdale project and other Pacific Highway upgrade projects including the adjoining Ballina bypass.

The sectional approach ensures an optimal result, as it provides larger areas of land of greater ecological significance, that are better able to be linked to land that is already protected. This approach has also been used successfully on other sections of the Pacific Highway upgrade program. The agreement already reached with the DECC provides for an area of 355 ha to be provided by the RTA as an offset for residual impacts of approximately 51 ha across all projects within section 5 (and includes any project modifications and minor works, which result in small scale variations to areas cleared).

12.4.3 Loss of threatened plant species

Known locations of threatened plants would be avoided where possible and fenced to protect them from direct and indirect impacts, particularly those species that occur on the edge of the study area (*Macadamia tetraphylla, Tinospora tinosporoides, Diploglottis camfieldii and Syzygium moorei*). This may involve fencing to keep out construction vehicles and prevent stockpiling. Contractors would be advised of the presence of the threatened plant species and measures required to protect them. Where threatened plants cannot be protected in-situ, translocation of the plants and collection of propagation material would be considered. A translocation plan would be prepared in consultation with the local council, the Department of Environment and Climate Change (DECC) and the local Botanic Gardens.

12.4.4 Loss of significant fauna species

Given the small amount of habitat available for significant fauna species, no specific management measures are proposed beyond those identified in **Sections 12.4.1, 12.4.5** and **12.4.7.**

12.4.5 Habitat fragmentation and barrier effects

During the design and selection of the preferred route a number of features were included to reduce the effects of habitat fragmentation. For example, the proposed upgrade was located where possible disturbances to one side of an area of vegetation rather than through the middle.

To further mitigate the impacts of fragmentation it is proposed that:

> Only native and locally indigenous plants would be used in the landscaping.

> Detailed bridge design and associated landscape treatment would encourage continuity of habitat along riparian corridors.

12.4.6 Edge effects and weed infestation

Mitigation measures related to edge effects relate generally to reducing impacts outside the direct development zone, controlling possible impacts at their source within the road reserve and reducing the hardness of the edge between the extent of earthworks and native vegetation. Measures to be adopted include:

> Avoiding stockpiling materials adjacent to native vegetation.

> Managing general construction activities to dispose appropriately of waste material and/or contaminants away from adjacent native vegetation.

> Implementing soil erosion and sedimentation control measures.

> Implementing a weed management strategy within the road reserve.

> Using locally indigenous (local provenance) species where possible for landscape plantings and revegetation.

12.4.7 Mortality

Minimisation of mortality of fauna during construction would involve implementation of management measures listed in **Section 12.4.1.**

During operation, a number of additional measures would be implemented to minimise road kill, including:

> Appropriate fencing in the vicinity of bridges to further encourage wildlife into riparian corridors and away from the road carriageways.

> Avoidance of overhanging vegetation that may encourage certain fauna species to enter the road reserve.

> Avoidance of plant species in the median and verge that are likely to encourage fauna vulnerable to road kill.

12.4.8 Aquatic ecology

Management measures to minimise impacts on aquatic ecology would include:

> A range of water quality management measures during construction and operation (refer to **Chapter 10)**.

> Compliance where feasible, in the detailed design of culverts, with NSW Fisheries *Guidelines and Policies for Aquatic Habitat Management and Fish Conservation* (Smith and Pollard 1999) and fish passage requirements for waterway crossings (Fairfull and Witheridge 2003).

> Undertaking restoration of riparian vegetation (as per **Section 12.4.1**).

> Minimisation of ground disturbance on creek banks and in-stream bed disturbance through appropriate detailed design of bridges and culverts and construction procedures.