Roads and Traffic Authority

Pacific Highway Upgrade - Oxley Highway to Kempsey

Flora and Fauna Working Paper

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4. Impacts on biodiversity

4.1 Overview

Strips and patches of natural vegetation throughout the study area would be permanently removed or modified by the Proposal. This includes some areas that qualify as endangered ecological communities under the TSC Act and/or contain threatened species or threatened species' habitat. The condition of the vegetation that would be affected varies throughout the study area, ranging from high levels of weed invasion and degradation in edge areas and disturbed areas, to moderate or negligible levels of degradation in areas more remote from the existing highway.

In terms of threatened flora species, the Proposal could potentially directly affect habitat for one species, scented acronychia, which was recorded in the study area during the route options assessment (HWR Ecological 2005a). This species was not detected in subsequent targeted field investigations undertaken by Ecotone for the Proposal and may have been mistaken for a similar species recorded in the approximate location of one of the previous records near Fernbank Creek.

Four endangered ecological communities (EECs) would be impacted by the Proposal in the form of direct clearing. Adjacent retained habitat of these communities could also be indirectly affected by runoff, weed invasion and edge effects. The extent of impact on each of the EECs is discussed in **Section 4.2**.

Eighteen threatened fauna species have been positively identified within the study area as a result of field investigations within the study area. An additional 30 species are considered to have potential to occur based on the results of the literature review and habitat assessment. Direct impacts on a number of species could occur as a result of the Proposal and these are discussed in **Section 4.4**.

The Proposal would result in the removal of mangroves at the Hastings River and Wilson River crossings, and the removal and overshadowing of seagrass at the Hastings River crossing. These impacts are discussed further in **Section 4.12**.

No threatened fish species were recorded in the study area and the watercourses to be affected by the Proposal are not considered to support suitable or important habitat for threatened fish. No endangered populations of flora or fauna would be impacted by the Proposal. No areas of critical habitat declared on the Registers of Critical Habitat kept by DECCW, DII, DEWHA, occur in the study area.

4.2 Loss of native vegetation

Approximately 203.1 hectares of native vegetation would need to be cleared within the Proposal footprint, as outlined in **Table 4-1**. An additional 81.3 hectares of artificial/highly modified communities would also be cleared for the Proposal.

Table 4-1 Vegetation clearance

Vegetation community	Predicted impact area
Natural communities	
1 Moist Floodplain Closed Forest with Rainforest Elements	3.9 ha
2 Riparian Forest	7.8 ha
3 Paperbark Swamp Forest	9.5 ha
4 Swamp Mahogany/Forest Red Gum Swamp Forest	10.4 ha
5 Swamp Oak Forest	0.9 ha
6 Wetland	3.8 ha
7 Moist Floodplain Forest	27.8 ha
8 Moist Gully Forest	25.8 ha
9 Moist Slopes Forest	73.9 ha
10 Dry Ridgetop Forest	39.3 ha
Total natural communities	***203.1 ha***
Artificial or highly modified communities	
11 Cleared – Scattered Trees	18.6 ha
12 Plantation/Cropland/Market Garden etc.	1.4 ha
13 Totally Cleared Open Pasture/Weedy Fallow	61.3 ha
Total highly modified communities	***81.3 ha***
Total natural and highly modified communities	**284.4 ha**

Of the native vegetation to be cleared, approximately 36.3 hectares qualifies as EECs listed under the TSC Act, as shown in **Table 4-2**. Four EECs would be directly impacted within the Proposal footprint to some degree. The greatest impact would occur on Swamp Sclerophyll Forest on Coastal Floodplains, followed by Subtropical Coastal Floodplain Forest. The least impact would be on Swamp Oak Floodplain Forest, followed by Freshwater Wetlands. Of the total area of intact natural vegetation subject to direct impact by the Proposal, approximately 12.8 per cent consists of EECs.

An assessment of the extent of impacts on EECs in a regional context is outlined in **Section 4.15**.

The total area of native vegetation, including EECs, to be cleared does not include potential indirect impacts in areas of retained vegetation adjoining the Proposal footprint. Runoff of sediment, nutrients and pollutants could directly impact on the habitat of both ecological communities and threatened species during both the construction and operation phases of the Proposal. There is also the potential for modification of retained habitats as a result of edge effects, including the establishment of weeds.

Targeted management and control of runoff as well as direct control of noxious and environmental weeds and rehabilitation of disturbed areas would be an integral part of the Proposal, during both the construction and operation phases (see **Section 6**).

While the proposed vegetation clearing is unlikely to result in the local extinction of any threatened flora or fauna species or EEC, the Proposal is considered likely to contribute to the cumulative effects of habitat loss affecting these species and EECs in the region. Refer to **Section 5**, **Appendix I** and **Appendix J** for assessments of significance of impacts on threatened species and EECs under Part 3A of the EP&A Act and the EPBC Act.

Table 4-2 Extent of impact on endangered ecological communities in the Proposal footprint

Endangered ecological community	Endangered ecological community as a percentage of total area of natural vegetation	Area and percentage of endangered ecological communities directly affected
Swamp Sclerophyll Forest Vegetation communities 3 and 4	7.0%	19.9 ha (55%)
Swamp Oak Floodplain Forest Vegetation community 5	0.3%	0.9 ha (2%)
Subtropical Coastal Floodplain Forest Vegetation communities 1 and 2	4.2%	11.7 ha (32%)
Freshwater Wetlands Vegetation community 6	1.3%	3.8 ha (11%)
Total	**12.8%**	**36.3 ha (100%)**

4.3 Loss of threatened plants

No threatened flora species were recorded within the study area during the terrestrial flora surveys as described in **Section 3.5**. However, as a precautionary measure an assessment of the possible impact of the Proposal on seven threatened flora species that may potentially occur in areas of suitable habitat within the Proposal footprint has been undertaken.

An assessment of the likely significance of impacts on these threatened plant species has been prepared for these species on a precautionary basis assuming them to be present and is presented in **Appendix I** and **Appendix J**. The results of the assessment are summarised in **Section 5**.

4.4 Loss of fauna habitat

The clearance of native vegetation for the Proposal would result in the loss of habitat for fauna species, including areas of 'key habitat' associated with regional and subregional corridors mapped by the DECCW (NPWS 2005). Whilst some of the native vegetation that would be cleared is noted as occurring within mapped key habitat and corridor areas (**Figure 9**), this fact is not a determining factor in itself for the purposes impact assessment, but one of many factors to be considered in the overall assessment of impact.

Table 4-3 shows threatened species known to occur or which may potentially occur in the habitat types that are to be cleared, and the extent of the required clearing.

Table 4-3 Potential fauna habitat loss

	Vegetation community	Threatened fauna known or with potential to occur	Area impacted
Natural communities			
1	Moist Floodplain Closed Forest with Rainforest Elements	Barred cuckoo-shrike, insectivorous bats, common planigale, owls, fruit-doves, golden-tipped bat, green-thighed frog, grey-headed flying-fox, koala, pale-headed snake, spotted-tailed quoll, square-tailed kite, Stephens' banded snake, yellow-bellied glider.	3.9 ha
2	Riparian Forest	Barred cuckoo-shrike, insectivorous bats, common planigale, owls, giant barred frog, stuttering frog, green-thighed frog, grey-headed flying-fox, koala, pale-headed snake, southern myotis, spotted-tailed quoll, square-tailed kite, black bittern, yellow-bellied glider.	7.8 ha
3	Paperbark Swamp Forest	Barred cuckoo-shrike, insectivorous bats, common planigale, eastern chestnut mouse, owls, glossy black-cockatoo, green-thighed frog, grey-headed flying-fox, koala, long-nosed potoroo, regent honeyeater, swift parrot, spotted-tailed quoll, square-tailed kite, squirrel glider, wallum froglet.	9.5 ha
4	Swamp Mahogany/Forest Red Gum Swamp Forest	Barred cuckoo-shrike, insectivorous bats, common planigale, eastern chestnut mouse, owls, fruit-doves, glossy black-cockatoo, green-thighed frog, grey-headed flying-fox, koala, long-nosed potoroo, regent honeyeater, swift parrot, spotted-tailed quoll, square-tailed kite, squirrel glider, Stephens' banded snake, wallum froglet, yellow-bellied glider.	10.4 ha
5	Swamp Oak Forest	Barred cuckoo-shrike, insectivorous bats, owls, koala, square-tailed kite.	0.9 ha
6	Wetland	Giant dragonfly, southern myotis, Australasian bittern, Australian painted snipe, black-necked stork, comb-crested jacana.	3.8 ha
7	Moist Floodplain Forest	Insectivorous bats, common planigale, owls, glossy black-cockatoo, green-thighed frog, grey-crowned babbler, grey-headed flying-fox, koala, pale-headed snake, spotted-tailed quoll, square-tailed kite, squirrel glider, yellow-bellied glider.	27.8 ha
8	Moist Gully Forest	Barred cuckoo-shrike, insectivorous bats, common planigale, owls, fruit-doves, glossy black-cockatoo, green-thighed frog, grey-headed flying-fox, koala, long-nosed potoroo, pale-headed snake, spotted-tailed quoll, square-tailed kite, squirrel glider, Stephens' banded snake, yellow-bellied glider.	25.8 ha
9	Moist Slopes Forest	Brush-tailed phascogale, insectivorous bats, common planigale, owls, glossy black-cockatoo, green-thighed frog, grey-crowned babbler, grey-headed flying-fox, koala, pale-headed snake, regent honeyeater, swift parrot, spotted-tailed quoll, square-tailed kite, squirrel glider, yellow-bellied glider.	73.9 ha
10	Dry Ridgetop Forest	Brush-tailed phascogale, insectivorous bats, owls, glossy black-cockatoo, grey-crowned babbler, grey-headed flying-fox, koala, pale-headed snake, regent honeyeater, swift parrot, spotted-tailed quoll, square-tailed kite, squirrel glider.	39.3 ha
Total natural communities			***203.1 ha***

Vegetation community		Threatened fauna known or with potential to occur	Area impacted
Artificial or highly modified communities			
11	Cleared – Scattered Trees	Potential occasional visits by grey-headed flying-fox, swift parrot, regent honeyeater and insectivorous bats. Some large trees may provide potential roost sites for insectivorous bats or a potential nest tree for the osprey. These areas may also provide a corridor link for some species, in particular the koala.	18.6 ha
12	Plantation/Cropland/ Market Garden etc.	Potential occasional visits by grey-headed flying-fox, fruit-doves and insectivorous bats for foraging purposes.	1.4 ha
13	Totally Cleared Open Pasture/Weedy Fallow	Grass owl (in areas of long grass – mainly between Cairncross State Forest and the Wilson River) and black-necked stork (Hastings and Wilson river floodplains). Some insectivorous bats are likely forage above these areas.	61.3 ha
Total highly modified communities			***81.3 ha***
Total natural and highly modified communities			**284.4 ha**

The Proposal would result in the loss or modification of areas of 'potential' and 'core' koala habitat as defined under *State Environmental Planning Policy No. 44 – Koala Habitat Protection*, predominantly associated with swamp mahogany/forest red gum swamp forest (community 4), moist floodplain forest (community 7) and moist slopes forest (community 9), but also some areas of riparian forest (community 2) and moist gully forest (community 8). Areas where 'core habitat' would be lost or modified include in particular where natural vegetation occurs on either side of the road at the following locations: either side of Sancrox Road; Cairncross State Forest and Rawdon Creek Nature Reserve; Cooperabung Hill (Ballengarra State Forest and Cooperabung Nature Reserve); Mingaletta Road to Smiths Creek; Kundabung Road to north of Pipers Creek; and Maria River State Forest.

There is a potential for the Proposal to impact on breeding habitat for the green-thighed frog and giant barred frog where it traverses Maria River State Forest. A potential green-thighed frog breeding pool located during the summer survey period is located within the expected Proposal footprint within Maria River State Forest. Specific mitigation measures would be developed in consultation with DECCW to minimise adverse impacts on the population and to complement existing management of the species at this location. Both green-thighed frog and giant barred frog were recorded in Maria River State Forest (see **Figure 10**) and both have the potential to occur within riparian vegetation along other major freshwater creeks within the study area. The Proposal would utilise the recently constructed dual carriageway bridges at Maria River, however these species may still be impacted during construction of the Proposal in this area. The mitigation measures applied for the Maria River bridge construction would also be applied at Maria River and associated tributaries during construction of the Proposal, as well as Smiths, Piper and Cooperabung Creek (see **Section 6.1**).

4.5 Habitat fragmentation

Habitat fragmentation can result in reduced dispersal and reproductive success of biota within the fragment, a decline in populations resulting from increased predation by introduced species or native species that do not normally occur in the community, and an increased probability that stochastic events (eg fire) may reduce population numbers below critical levels required for their survival (Andrew 1990). In general, larger fragments are less susceptible to adverse impacts than are smaller fragments.

Larger stands of vegetation generally have greater species richness than smaller stands given that:

- They contain a greater sample of the original habitat and therefore are likely to sample a greater range of biota.
- They are able to support larger population sizes and hence more species are able to maintain viable populations than in a smaller areas.
- Larger areas are likely to contain a more diverse range of habitats for flora and fauna, with the number of species reflecting the diversity of available habitats (Bennett 1991).

However, the isolation of the fragment and the level of disturbance will also have an influence on the biodiversity present.

Ecosystem processes may be altered and ecological viability threatened in fragments over the longer-term as a result of ongoing ecological degradation (see Saunders, Hobbs & Ehrlich 1993). Plants and animals in isolated vegetation fragments will typically undergo alterations in population dynamics, including a reduction in biodiversity, negative genetic consequences, changes in species dominance and weed invasion. Small populations restricted to fragments are at greater risk of extinction compared with populations in larger, interconnected stands of vegetation.

The majority of the Proposal would involve constructing new carriageways adjacent to the existing Pacific Highway alignment. In these areas, there would be edge effects of vegetation clearing, and a widening of the barrier which is the existing highway, resulting in an incremental increase of habitat fragmentation. No new fragmentation of habitat would occur for most species in these areas. However for some species (for example, gliders), widening the existing highway would result in an increase in fragmentation of habitat as they are unlikely to be able to glide across the entire width of the upgraded highway.

For sections of the Proposal that would involve the construction of new alignment, there would be new habitat fragmentation. Areas along the Proposal route where there is potential for habitat fragmentation include:

- Fernbank Creek and the floodplains of the Hastings River.
- Cairncross State Forest and the floodplains of the Wilson River.
- Maria River State Forest.

The largest habitat fragment would be created where the proposed route deviates from the existing highway alignment through Cairncross State Forest and north to the Wilson River. At this location an 83 hectare triangle of bushland would be created between the existing and upgraded highway. The southern portion of this area forms part of an identified regional corridor and the remainder, although not formally identified in the corridor mapping, is contiguous with large tracts of vegetated land.

To reduce the potential for adverse impacts on native wildlife as a result of habitat fragmentation, dedicated fauna underpasses, combined drainage/fauna movement culverts, aerial fauna crossings and glider poles in conjunction with wildlife exclusion fencing have been incorporated into the Proposal design. The aim of these measures would be to maintain connectivity between stands of existing vegetation and facilitate continued fauna movements through the area (see **Section 6.3**). Specific mitigation measures to reduce the potential for adverse impacts on retained vegetation and habitats as a result of edge effects and weeds will also be implemented (see Section 6.2).

4.6 Barrier effects, road mortality and impacts on fauna movements and populations

Movement through the landscape is necessary for most native fauna to find food and shelter, breeding sites and partners and for the dispersal of young (Hussey et al. 1989). Roads can act as barriers to native fauna movements due to the introduction of gaps in protective cover, disturbance and modification of road side habitats, and general disturbance as a result of traffic noise and lights, movements and emissions (Bennett 1991; Glista et al. 2009). Roads can also have serious impacts on local fauna movements and populations through increasing mortality as a result of collisions with vehicles. In this respect, roads can greatly restrict the movements of species with limited mobility (eg small mammals, reptiles and amphibians) but may also adversely impact movements of terrestrial fauna of larger body size and those that are locally nomadic or which occupy large home ranges, such as macropods, larger reptiles and Koalas (Andrews 1990; Bennett 1991).

Roads have the greatest potential to act as a barrier where they intersect wildlife corridors used by fauna for movements through the landscape. The barrier effect can contribute to adverse impacts on native fauna by reducing genetic diversity within small sub-divided populations, increasing the probability of local extinctions of small population through stochastic events and reducing the likelihood of re-establishment of local populations after natural decline due to inhibition of immigration/recruitment by the barrier (Hunt et al. 1987; Taylor and Goldingay 2009). In the study area, vegetation connectivity is also important to enable seasonal movements between habitats on the coastal plain and fringing ranges.

As discussed in **Section 3.8.4** and shown in **Figure 9,** the Proposal passes through or overlaps nine regional and sub-regional corridors identified by DECC (NPWS 2005) and has the potential to exacerbate barrier impacts for native fauna in the locality. The Proposal also has the potential to impact on koala corridors near Sancrox Road, between the Hastings and Wilson rivers, Barrys Creek, Pipers Creek and Smiths Creek (Connell Wagner, 2000; Vanessa Standing pers. comm.).

The Proposal would result in a barrier through the landscape (in addition to the existing Pacific Highway and other roads and clearings) and could potentially impede native fauna movements in the locality where fauna are unwilling to attempt crossings or are subject to mortality as a result of vehicle collison. In addition to direct mortality, fauna populations could also be affected by the selective mortality of certain age classes or sex classes that may be more prone to undertake movements across road ways (for example, dispersing males) and in the longer-term this may affect the distribution and demographic characteristics of the population. The maintenance of corridor function and habitat connectivity between the coastal plain and ranges within the study area and locality is essential to ensure the long-term viability of existing fauna populations.

To reduce the potential for adverse impacts on native wildlife as a result of habitat fragmentation, barrier effects and road mortality, dedicated fauna underpasses and dual purpose drainage/fauna movement culverts in conjunction with wildlife exclusion fencing have been incorporated into the Proposal design (see **Section 6.3**).

Studies undertaken at other locations along the upgraded Pacific Highway (AMBS 2000-2002) have shown a wide range of fauna will use fauna underpasses of similar dimensions to those proposed as part of the Proposal. On this basis, it is considered reasonable to assume that fauna in the study area will utilise such features to cross the new road if appropriately designed and placed in the landscape.

4.6.1 Potential impacts on fauna groups and species

The Proposal traverses intact stands of vegetation comprising areas of key habitat that support high native species diversity and contribute to wildlife corridors likely to facilitate fauna movements through the landscape. The existing highway would be perceived as a barrier to movement by some species (most likely smaller cover-dependent and slow-moving, ground-dwelling species). Other species, including larger terrestrial ground-dwelling and arboreal fauna, would be more willing to attempt crossings in particular where habitat occurs adjacent to either side of the road. A wider gap and increase in vehicle speeds and movements is likely to contribute to the risk of vehicle strike for these species in the absence of appropriate mitigation measures to facilitate safe passage.

A discussion of the potential impacts of the Proposal on habitat connectivity for fauna groups and a selection of key threatened species of relevance to the study area is provided below. A detailed discussion of the impacts of the proposal on habitat connectivity and on specific threatened species recorded or which could potentially occur in the study area is provided in the Assessment of Impacts under the Part 3A threatened species assessment guidelines in Appendix I.

Proposed mitigation measures incorporated into the Proposal design to reduce the impact of barrier effects and road mortality, including the construction of wildlife exclusion fencing and fauna underpasses, are discussed in detail in **Section 6.**

Terrestrial mammals

Most small terrestrial mammal species are cover-dependent and are generally unlikely to attempt road crossings given the large open nature of the road way (Hunt et al. 1987). The new road has the potential to act as a barrier to movements of small mammals between areas of fragmented habitat but an increase in the incidence of road mortality for these species as a result of the Proposal is not anticipated. The proposed underpasses aim to facilitate the safe passage of small mammals under the road and to maintain habitat connectivity at these locations.

Medium to large terrestrial mammals (eg eastern grey kangaroo and swamp wallaby) which often forage along grassy road side verges and range widely in search of suitable foraging habitat are particularly susceptible to road strike (Bennett 1991). The proposed large dedicated fauna underpasses and combined drainage/fauna movement culverts in conjunction with fauna exclusion fencing aim to maintain connectivity between stands of existing vegetation and facilitate continued movements of larger mammals through the area.

Other small-medium sized mammals such as the spotted-tailed quoll can also be adversely impacted by roads. This species was not recorded within the study area during field survey work, though a few records occur nearby. DECCW's Atlas of NSW Wildlife indicates four main clusters of spotted-tailed quoll records (possibly sub-populations) associated with state forests and nature reserves located to the west side of the existing highway. Nearly all of the records are associated with creeklines within large patches of forest. East of the highway, the species appears to be generally absent, with only a few scattered records.

The spotted-tailed quoll is susceptible to road-related mortality as the species often scavenges on road kill. The lack of road kill database records along the existing highway within the study area suggests that this species is unlikely to use the highway corridor and adjoining habitats, particularly the drier ridgetop forests, on a regular basis, if it does at all. Furthermore, the current distribution of the species, as indicated by the existing records, suggests that core habitat for the species is not likely to be within habitats close to the highway and that the species is unlikely to move between habitats on each side of the highway on a regular basis.

At present, there is limited opportunity for mammals to move between habitats on either side of the existing highway, without crossing the highway. With the installation of new bridges and fauna crossings, there is opportunity to provide sufficient passage to allow mammals to transit safely between habitats on either side of the highway. A wide range of mammal species have been recorded using underpasses in gullies and drainage lines (AMBS 1997; AMBS 2001) hence are likely to use bridges and underpasses, providing dry passage is available.

Arboreal mammals

Arboreal mammals can potentially be vulnerable to adverse impacts of roads where areas of suitable habitat are separated. Recent studies have shown the common brushtail possum and common ringtail possum to be particularly susceptible to road mortality as a result of collisions with vehicles (Russel et al. 2009; Hobby and Minstrell 2008).

Koalas are also highly susceptible to road mortality, in particular dispersing young and individuals seeking mates during the breeding season. The existing highway already bisects wildlife corridors through the study area and impedes movements and recruitment processes through regular road mortality of numbers of individuals as evidenced by koala road kill records (see **Figure 7**).

At the southern end of the study area a subregional wildlife corridor known to be used by the koala crosses the existing highway between the Oxley Highway and Sancrox Road and road widening would potentially increase the risk of death or injury resulting from vehicle strike. The Proposal would also widen the existing gap where a regional wildlife corridor is mapped as connecting either side of Cairncross State Forest and Rawdon Creek Nature Reserve across the existing highway. Other areas where the study area crosses mapped wildlife corridors are at Cooperabung Creek Nature Reserve, Ballengarra State Forest, vegetation along Smiths Creek and Pipers Creek, Maria River State Forest, Kumbatine National Park and Kalateene State Forest. Again, while the existing highway already presents a barrier to koala movement, the proposed widening of the highway would increase this gap and decrease the effectiveness of these corridors in facilitating safe koala movement.

Based on the Wildlife Atlas records and communication with local veterinarian and koala expert, Vanessa Standing, this species could occur anywhere along the proposed route, particularly where natural vegetation occurs on either side of the road.

However, the most likely areas, based on available records, appear to be (in order from south to north):

- Either side of Sancrox Road.
- Cairncross State Forest and Rawdon Creek Nature Reserve.
- Cooperabung Hill (Ballengarra State Forest and Cooperabung Nature Reserve).
- Mingaletta Road to Smiths Creek; Kundabung Road to north of Pipers Creek.
- Maria River State Forest.

Based on the information from the Port Macquarie Koala Hospital and Vanessa Standing, the chance of further koala road fatalities is high. The widening of the highway as a result of the Proposal may increase the risk of road death for the koala as animals will have further to travel across the additional lanes to move between vegetated areas.

The project is also expected to result in the loss of a long strip of koala habitat along the proposed route, including the loss of koala food and shelter trees. Where the proposed route deviates from the existing highway and through currently intact native vegetation in Cairncross State Forest, this may cut through individual koalas' home territories, forcing them to cross the new highway in order to move between food and shelter trees. This could potentially result in some koalas being displaced from their current territories and may also impact on the dispersal ability of the koala.

The Proposal is unlikely to directly disrupt the breeding cycle of the koala, although the deviation through Cairncross State Forest could isolate females from the breeding male if the road passes through the male's territory. However, the Proposal is likely to lead to increased fragmentation and isolation of koala habitat within the study area and this could potentially affect koala home ranges and the social structure of the population.

Dedicated fauna underpasses and combined drainage/fauna movement culverts in conjunction with wildlife exclusion fencing incorporated into the Proposal design will be important to maintain connectivity between stands of existing vegetation and facilitate safe koala movements through the study area (see **Section 6.3**).

The Proposal has been intentionally designed to minimise the potential for koala road mortality through the incorporation of large dedicated underpasses and wildlife exclusion fencing through the western portion of the study area where the most extensive areas of Koala habitat are located. Such features in conjunction with aerial fauna crossings (see below) are also intended to facilitate the safe passage of other arboreal fauna species, such as possums, across the road.

For gliding species, the existing highway is already likely to present some form of barrier to movement. However given the glide distances these species are capable of, it is likely that both the yellow-bellied glider and squirrel glider would be able to cross the existing highway along most areas where large tracts of vegetation occur on either side of the road. Based on the concept design and width of the presumed impact area, the widening of the road corridor is expected to extend this gap beyond the comfortable glide distance for both species along much of the study area. While the yellow-bellied glider is expected to be able to achieve the required glide distance at least in some areas along the route, glides of over 50 metres are likely to be required along the majority of the route and this is expected to pose a difficulty for the squirrel glider.

To reduce the potential for adverse impacts on gliders a combination of aerial fauna crossings and glider poles have been incorporated into the Proposal to enable gliders to successfully glide across the road (see **Section 6.3**). If gliding remains possible, these species are unlikely to suffer from road mortality given the height at which they glide (Goldingay & Kavanagh 1991).

Bats

The Proposal is unlikely to impose a barrier to the movement of bat species which are generally capable of traversing large gaps in vegetation. Whilst species that forage along the transition between forest and open areas may potentially be susceptible to road strike, most species would fly between the canopies on either side of the road and remain at a safe height above the traffic.

Birds

Most bird species would be able to readily traverse the road and generally fly at canopy height remaining a safe height above the traffic. Species, such as glossy black cockatoos and grey-crowned babblers, that can often fly at lower elevations may potentially be at greater risk of vehicle strike.

Bird species that forage along road edges and in road reserves, including seedeaters (eg parrots and cockatoos), predators (eg owls and raptors) and carrion feeders (eg raptors and ravens) are often subject to high rates of road mortality (Bennett 1991). Waterbird mortalities can also occur along roadsides adjacent to low-lying wetland habitats due to low approach flights over the road.

Frogs and reptiles

Frogs and reptiles are susceptible to road mortality due to their relatively poor mobility. Mortality is often closely linked to season and results from animal responses to fluctuations in temperature and rainfall (Bennett 1991). Frog mortality can result from attempted road crossings between breeding and non-breeding habitats following rain periods and reptile mortality often results from individuals basking on warmed road surfaces. There is the highest potential for adverse impacts on frog species where the proposed road crosses riparian corridors and low-lying floodplains. Proposed bridges and dual-purpose drainage/fauna movement culverts incorporated into the road design should enable the safe passage of frogs and reptiles under the road.

4.7 Fauna mortality during construction

Fauna most susceptible to mortality during clearing include less mobile species and in particular nocturnal hollow-roosting fauna, such as arboreal mammals and microchiropteran bats. A range of pre-clearing survey protocols would be implemented during the construction phase of the Proposal, including inspections of hollow-bearing trees and staged clearing, to minimise the chances of death or injury to native fauna during the clearing and construction phases (refer **Section 6.1**).

4.8 Edge effects

Laurance (1997) defines edge effects as a diverse array of biotic and physical changes associated with the abrupt, artificial margins of forest fragments. Edges cause alterations in temperature, humidity, light, nutrients, exposure and moisture availability and allow the establishment of opportunistic, 'edge specialist' species that may displace native species. On average, edge effects have been estimated to occur up to 50 metres from the road edge (Bali 2005), although much greater distances have been recorded in some road studies (Forman *et al*. 2003).

The smaller more isolated fragments of vegetation in the study area are already affected by edge effects to varying extents. The greatest potential for adverse impacts as a result of edge effects where the Proposal would traverse large stands of vegetation in state forests. Potential edge effects in these areas as a result of the Proposal include:

- Establishment of weeds along disturbed vegetation boundaries and their incursion into native vegetation.
- Modification of habitat attributes and displacement of fauna assemblages.
- Displacement of woodland and forest bird assemblages by edge specialists.
- Increased predation of birds, small mammals, reptiles and frogs by raptors and owls which may use forest edges as foraging sites.
- Increased nest predation of small insectivorous birds at forest edges.

A range of impact mitigation measures are to be implemented to minimise edge effects on retained native vegetation within the study area, including replanting of the road reserve with local native plant species and the implementation of a weed control and management program (see **Section 6.2**).

4.9 Weeds

There is the potential for the introduction of weeds where the Proposal traverses intact stands of native vegetation. Construction also has the potential to introduce or spread root rot *Phytophthora cinnamomi*. Seven weeds recorded are declared noxious under the *Noxious Weeds Act 1993*, including lantana, the most abundant and widespread weed in the study area. The 'invasion, establishment and spread of lantana' is listed as a key threatening process under the TSC Act.

Mitigation measures to be implemented during the construction and operational phases of the Proposal include strategies for the management and control of noxious and environmental weeds (see **Section 6.2**).

4.10 Changed hydrology

No significant alterations to the existing hydrology of the floodplain areas or associated impacts on watercourses or aquatic habitats are anticipated as a result of the Proposal. Measures to facilitate fish and amphibian crossings would be incorporated into the detailed design in accordance with the *Policy and Guidelines for Fish Friendly Waterway Crossings* (DPI 2003) to avoid modification of the natural hydrology of the creeklines and rivers within the study area.

4.11 Aquatic habitat disturbance

4.11.1 Riparian corridors and aquatic habitat

Potential impacts on aquatic habitat and riparian corridors could occur as a result of the construction and operation of the Proposal. New crossings would be constructed for Fernbank Creek, Hastings River, Wilson River, Cooperabung Creek, Barrys Creek, Smiths Creek, Pipers Creek and Stumpy Creek. The construction of the new crossings would involve vegetation removal, and impacts on habitat within the riparian corridors. Approximately 7.8 hectares of riparian forest would be cleared for the Proposal.

Twin bridges would cross Fernbank Creek. While Fernbank Creek is primarily a flood relief channel for the Hastings River, it does support a well vegetated riparian corridor and a section of endangered ecological community. The construction of the twin bridges across Fernbank Creek would result in the clearance of vegetation and overshadowing of remaining sections of vegetation.

Twin bridges would cross the Hastings River approximately 300 metres to the west of the existing Dennis Bridge crossing location. The proposed twin bridges would require the clearance of mangroves and seagrasses, and would overshadow seagrass communities in the river (see **Section 4.12**).

Twin bridges would cross the Wilson River, which is tidal within the study area and supports interrupted riparian bands of mangroves as well as patches of broader estuarine wetlands. Several of the wetland areas along the Wilson River are listed under *State Environmental Planning Policy No. 14 – Coastal Wetlands*, specifically wetland no. 484f, on Dalhunty Island, and wetland 484e, on the adjacent northern bank of the Wilson River.

Creek crossings at Cooperabung Creek, Smiths Creek, Pipers Creek and Stumpy Creek would involve the construction of new bridges. The construction of these bridges would result in vegetation clearance and overshadowing of remaining vegetation. Culverts would be constructed for the Barrys Creek crossing.

At all proposed bridge crossings, construction would involve a disturbance area approximately 80 to 90 metres wide at the abutments, which would be set back from the bank. Bridges would be designed to assist in maintaining riparian connectivity and movement opportunities for native fauna along the banks of watercourses. Indicative specifications for proposed watercourse crossings and fauna that may potentially use proposed structures are provided in **Section 6.3.1**.

Potential impacts on water quality could occur during the construction stage through vegetation clearance and disturbance to banks and during the operation of the Proposal as a result of sedimentation in runoff or from contaminants (for example, chemical and fuel spills). Measures to minimise impacts to riparian and aquatic habitat are contained within **Section 6.4**..

4.11.2 Aquatic fauna

The Proposal is unlikely to have an adverse impact on fish assemblages in the watercourses of the study area given the implementation of specific design elements and mitigation measures to avoid impacts on water quality, riparian and aquatic vegetation and fish passage (see **Section 6.4**).

No threatened fish species were recorded during the aquatic field surveys. The Oxleyan pygmy perch is considered unlikely to occur in the study area given the general absence of suitable habitat in the majority of watercourses to be impacted by the Proposal and the dense populations of mosquito fish (*Gambusia holbrooki*) recorded in local watercourses that may otherwise support potential habitat for this species.

The Proposal has the potential to result in disturbance to the bed and bank of creeks during construction, resulting in impacts to aquatic habitat. However, the mitigation measures described in **Section 6.4** would assist in avoiding or minimising such impacts.

4.11.3 Impacts on fish passage

Three species identified during the aquatic survey (striped gudgeon (*Gobiomorphus australis*), short-finned eel (*Anguilla australis*) and long-finned eel (*Anguilla reinhardtii*) require unregulated longitudinal movement to facilitate and complete successful life cycles so that future generations could continue. The interruption of this could have a serious detrimental effect on the population dynamics of instream fauna.

The Proposal has the potential to result in disturbance to the bed and bank of the watercourse during construction, resulting in impacts to aquatic habitat. However, the mitigation measures described in **Section 6.4** would assist in avoiding or minimising such impacts.

The Proposal is highly unlikely to have any adverse impact on fish passage given that proposed watercourse crossings would comply with the *Policy and Guidelines for Fish Friendly Waterway Crossings* (DPI 2003).

4.12 Mangroves and seagrasses

The Proposal would pass through areas on the Hastings and Wilson rivers that contain mangroves, and areas of seagrasses on the Hastings River.

Impacts to mangroves and seagrass from the crossing of the Hastings River, and mangroves from the crossing of the Wilson River are largely unavoidable, in that in the worse case scenario species would be impacted through shading, despite design efforts to minimise overshadowing. The construction of the proposed twin bridges over both the Hastings and Wilson rivers would require the clearance of a discrete section of the mangroves that line the banks of both rivers. While care would be taken to minimise the areas required for clearance during construction, the long-term viability of the mangroves in the areas immediately under the bridge abutments would be compromised due to overshadowing. Effects on the mangroves would be limited to the area immediately under the proposed bridges, and the mangroves not affected by overshadowing would not be impacted.

A small area of seagrass would be cleared at the Hastings River crossing. The long-term viability of the seagrass beds under the proposed twin bridges over the Hastings River may be affected due to overshadowing. Effects would be limited to the areas immediately under the proposed bridges and seagrass beds not affected by overshadowing would not be impacted. However the shadowing effects would potentially fragment the seagrass beds in this locality, potentially resulting in two seagrass beds separated by the area affected by overshadowing.

The exact area of mangroves and seagrasses to be directly impacted by the Proposal would be determined at the detailed design stage when the precise dimensions of the structure and related overshadowing impacts can be determined. However, an approximate area of mangroves and seagrasses to be directly impacted within the clearing footprint (a 6 metre buffer from the edge of the Proposal) and potentially impacted as a result of shadowing (a 10 metre buffer from the edge of the Proposal, including the 6 metre buffer) at the Hastings and Wilson river crossings in the worst case scenario is presented in **Table 4-4**. A 10 metre buffer has been used to calculate the potential impacts as a result of shadowing, given that mangrove and seagrass vegetation currently occurs at a distance of 10 metres from the existing bridges over these rivers, and a similar shadowing impact would be anticipated with the new structures.

Table 4-4 Estimated worst case scenario impacts of the Proposal on protected marine vegetation at the Hastings and Wilson river crossings

Protected marine vegetation	Impacted area (ha)	
	6 metre buffer	10 metre buffer
Hastings River		
Mangroves	0.003	0.004
Seagrass	0.023	0.028
Wilson River		
Mangroves	0.030	0.033

Note: The area impacted in the 10 metre buffer includes the area impacted in the 6 metre buffer

The Proposal would be designed to minimise impacts on protected aquatic vegetation at the Hastings and Wilson River crossings, and in particular at Dalhunty Island, as far as is practicable. Mitigation measures would also be implemented to minimise impacts on protected marine vegetation at the Hastings and Wilson River crossings (see **Section 6.4**).

There is some potential for indirect impacts on mangroves, seagrasses and saltmarsh where they occur downstream of proposed river crossings as a result of erosion and sedimentation during bridge construction. Potential indirect impacts on aquatic vegetation downstream of bridge crossings would be controlled through the implementation of erosion and sedimentation mitigation measures implemented during the construction phase (see **Section 6.4.4**). There is limited potential for such impacts on saltmarsh communities given that the nearest downstream community is located approximately 10 kilometres downstream of the proposed Wilson River crossing.

There is also potential for indirect impacts on seagrasses and mangroves as a result of increased flow velocity and associated scouring, turbidity and sedimentation, in the vicinity of the proposed bridges over the Hastings and Wilson rivers. These bridge crossings are subject to detailed design and the potential for increased flow velocities cannot be accurately identified until the final design and configuration of bridge piers is known. However, such impacts are expected to be highly localised and only small increases in flow velocities have been predicted in the channel centre and at bridge abutments as a result of the Proposal: approximately 0.3 metres per second at the Hastings River crossing; and up to 0.2 metres per second at the Wilson River crossing (Worley Parsons 2010). Potential impacts on aquatic vegetation as a result of increased flow velocities at bridge crossings would be minimised through bridge design and the implementation of scour protection and other measures to minimise impacts on geomorphology (see **Section 6.4.4**).

4.13 Wetlands

Two wetlands listed under *State Environmental Planning Policy No. 14 – Coastal Wetlands* occur in association with the Wilson River: wetland no. 484f on Dalhunty Island; and wetland no. 484e on the northern bank of the Wilson River (see **Figure 11**). The State listed wetlands on Dalhunty Island comprise areas of mangrove forest, closed shrubland and swamp oak swamp forest. On the northern banks of the Wilson River, the State listed wetland comprises a small area of treeless freshwater wetland and swamp oak floodplain forest. The freshwater wetland is disturbed by cattle movements and grazing during periods of low inundation. The surrounding swamp oak forest is in relatively good condition, although the understorey has been grazed by cattle.

The Proposal would involve the construction of twin bridges across the Wilson River. The twin bridges would span the eastern portion of Dalhunty Island. Clearing of vegetation and State listed wetland area on Dalhunty Island is not proposed. While the final form and configuration of the twin bridges would be determined at the detailed design stage, all care would be taken to avoid placing piers on the island itself, and thereby reduce impacts on the State listed wetland on Dalhunty Island to overshadowing impacts.

Approximately 1 hectare of State listed wetland on the northern bank of the Wilson River would be cleared to accommodate the bridge abutments. The bridge abutments would be located at the western edge of the State listed wetland area, and would not result in the severance of this wetland.

The mapped boundaries of the above wetlands (Adam *et al.* 1985) were revised based on qualitative observations during field investigations undertaken during the route options assessment (HWR Ecological 2005a). A more accurate boundary would be established at the detailed design stage through quantitative observations and surveying of the mapped boundary to enable more accurate quantification of the area of impact and to assist in the refinement of proposed management measures.

Other areas of wetlands occur within the Proposal footprint associated with low-lying and riparian areas. These areas of wetland have been mapped as wetland, swamp oak forest and paperbark swamp forest vegetation communities.

The Proposal has the potential to impact on wetlands during construction through clearing of vegetation, erosion and sedimentation impacts. The loss of these wetland vegetation types has been assessed in **Section 4.2**. The significance assessments in **Appendix I** and **Appendix J** have concluded that there is unlikely to be a significant impact on vegetation communities provided that proposed mitigation and management measures are developed and implemented. Targeted management and control of runoff as well as direct control of noxious and environmental weeds and rehabilitation of disturbed areas would be an integral part of the Proposal.

No significant alterations to the existing hydrology of the floodplain areas or associated impacts on watercourses or aquatic habitats are anticipated as a result of the Proposal. Indirect impacts to wetlands through changes in hydrological regimes as a result of the Proposal are therefore considered unlikely.

4.14 Groundwater dependent ecological communities

The specific construction techniques would be determined at the detail design stage, and accordingly, the assessment of potential impacts on groundwater dependent ecological communities is necessarily general in nature. The likely impacts of construction on groundwater are discussed in Chapter 14 of the Environmental Assessment. These impacts are summarised and their relevance to potential groundwater dependent ecological communities addressed in **Table 4-5**. Much of the discussion of groundwater dependent ecological community impacts focuses on the vegetation, but there is an implied understating that the vegetation provides habitat for fauna species which may also be affected.

Key potential impacts to groundwater dependent ecological communities related to these threats include alteration of the water regime experienced by groundwater dependent ecological communities resulting in changes in the structure, function and/or composition of the ecosystem (Sinclair Knight Merz 2001) as well as the potential for detrimental changes to the groundwater quality to impact upon the vegetation. It is noted that impacts associated with lowered water tables upon groundwater dependent ecological communities could take place over an extended time and could lead to decline in growth, recruitment and enable invasion by exotic species (Eamus 2009).

Concern for construction impacts on groundwater dependent ecological communities are most likely to arise from groundwater drawdown in the vicinity of groundwater dependent ecological communities. It is therefore important that any dewatering proposed in the detailed design include consideration of impacts on groundwater dependent ecological communities, and should also include provisions for monitoring both groundwater levels and condition of nearby groundwater dependent ecological communities.

Table 4-5 Potential general impacts on groundwater dependent ecological communities

Potential impact	General description	Implications for the Proposal	Potential implications for groundwater dependent ecological communities
Impediment to groundwater flow by fill embankments	The placement of fill materials on soft floodplain soils leads to compaction of the underlying soil. The compacted soil is less permeable and can impede groundwater flows.	Embankments on the Hastings and Wilson river floodplains would be expected to be generally perpendicular to the rivers and, therefore, parallel to groundwater flows. Impacts on groundwater flows would thus be minimal.	Based on the assumption that groundwater flows are generally parallel to the proposed embankments, it is reasonable to assume that construction of the embankments would have negligible impact on groundwater dependent ecological communities in the vicinity of the road.
Impediment to groundwater flow by cuttings	Cuttings have the potential to impede groundwater flow by intersecting the aquifer and severing the link between opposite sides of the road. As cuttings are required where there are hills, the main impact is likely to be on confined bedrock aquifers in, for example, sedimentary rock strata.	The groundwater in the Proposal area is largely alluvial (plus sand bed groundwater also occurring to the east). Cuttings are unlikely to interfere with alluvial (or sand bed) groundwater due to the locations of cuttings in hillier areas rather than on the alluvial plains.	Groundwater dependent ecological communities in the study area are associated with alluvial rather than bedrock aquifers, and no impacts on groundwater dependent ecological communities are anticipated from cuttings.

Potential impact	General description	Implications for the Proposal	Potential implications for groundwater dependent ecological communities
Groundwater drawdown	Groundwater drawdown may result from use of wick drains to accelerate consolidation of soft soils, de-watering during bridge and culvert construction, and any groundwater extraction for use during construction.	Activities that could result in groundwater drawdown are most likely to occur in alluvial areas. However, potential drawdown is expected to be of limited duration and of limited spatial extent, although this is not defined at this stage.	As the identified groundwater dependent ecological communities mostly occur on the alluvial floodplains, they are theoretically vulnerable to groundwater drawdown in these areas. The impacts of any drawdown on groundwater dependent ecological communities would depend on the proximity of the groundwater dependent ecological communities to the construction works, the natural variability of the groundwater in that area, the duration of the drawdown, and the spatial extent of the drawdown.
Discharge of excess water to the environment	Discharge of collected stormwater or excess extracted groundwater to the environment could result in a localised mounding of the watertable in the vicinity of the discharge point.	The volume, duration and location of any discharge are critical to any potential impacts. While such discharges are expected to be minor, consideration of location of discharge points could mitigate potential impacts.	The impact on groundwater dependent ecological communities would depend on the location of the discharge point relative to groundwater dependent ecological communities and the volume and duration of discharge. Prolonged discharge could result in localised dieback, whereas intermittent or short-term discharge would be likely to result in no evident changes.
Groundwater quality impacts	Both water level and chemistry changes can potentially affect groundwater dependent ecological communities. Water chemistry changes that can have the most significant effects are changes to salinity, pH and macronutrients, as these are major drivers of ecosystem variability. However, relatively small quantities of some chemicals, such as petrochemicals, may also have toxic effects on groundwater dependent ecological communities.	Potential construction impacts on groundwater quality are disturbance of acid sulfate soils, chemical spills, and saline intrusion during dewatering near the rivers. The first two can be managed as part of standard operational procedures and would not result in changes in groundwater chemistry if correctly managed. The extent of saline water intrusion would be dependent on river conditions at the time of the works, and on the duration of the dewatering.	None of the identified freshwater groundwater dependent ecological communities in the vicinity of the corridor occur close to either the Hastings or the Wilson rivers, and dewatering for bridge construction in these areas is unlikely to result in saline groundwater intrusion impacts. The other potential impacts should be effectively managed at source and not impact groundwater dependent ecological communities.

Although some of the vegetation communities within the study area are likely to be groundwater dependent, the Proposal is not likely to result in significant drawdown of groundwater, groundwater impedance or changes to the groundwater quality such that these ecosystems would be significantly detrimentally impacted.

4.15 Regional cumulative impacts

Cumulative impacts of the Proposal have been considered in terms of the additive impacts of multiple activities within the Mid-North Coast Region of NSW (as defined by NPWS 1999). As discussed in **Section 3**, the Proposal lies within a landscape impacted by several past and present land uses and activities. These impacts include clearing for agriculture and grazing land uses as well as removal of timber during logging operations. Much of the existing vegetation is regrowth from past major disturbances such as logging or clearing for farming and grazing.

The Proposal is part of the Pacific Highway Upgrade Program that includes several sections of the Pacific Highway that have been upgraded or are currently under construction within the North Coast Bioregion, which the Mid-North Coast Region forms part of. The remainder of the Pacific Highway in this bioregion is to be upgraded in the future.

The Proposal is also one of many developments planned or underway in the Mid North Coast Region of NSW (NPWS 1999). These developments, along with the Proposal, would all contribute to the cumulative additive impacts of development in the area and include the following large-scale projects within a 20 kilometre radius of the Proposal area:

- Oxley Highway upgrade.
- Area 13 Thrumster Urban Investigation Area to the east of the Proposal.
- Proposed industrial development on the western side of the Proposal, south of Sancrox Road.
- A possible marine development on the Hastings River in the vicinity of the existing highway.
- Le Clos Verdun rural residential re-subdivision in Sancrox Road, about 5 kilometres to the west of the Proposal.
- Upgrade of the existing Transgrid 132 kV transmission line between Kempsey and Port Macquarie, generally to the east of the Proposal.
- Area 14 Rainbow Beach urban investigation area, about 15 kilometres to the south-east of the Proposal area.
- Area 15 Camden Haven urban investigation area, about 20 kilometres to the south of the Proposal area.

The Proposal, combined with these and other large-scale developments in the region, would contribute to cumulative flora and fauna impacts in the region, including loss of native vegetation, loss of threatened species, and loss of fauna habitat. Each of these projects, including the Proposal, would implement mitigation measures at a local level to offset these impacts.

4.15.1 Endangered ecological communities

As discussed in **Section 4.2**, the Proposal would impact four EECs. *The Comprehensive Regional Assessment of North Eastern NSW* (NPWS 1999), undertaken as part of the regional forest agreement process, mapped broad floristic groups and forest structure to guide modelling of forest ecosystems, old growth forest, and flora and fauna communities in north-eastern NSW. This mapping provides a useful basis to assess the extent of impacts on EECs in a regional context.

Table 4-6 summarises the extent in the Mid-North Coast Region of these four EECs found in the Proposal area, as at 1999 when the National Parks and Wildlife Service assessment was carried out. The table shows the four EECs that would be impacted by the Proposal, the corresponding vegetation community as it was described in the Comprehensive Regional Assessment mapping, the extent of each EEC in the Region (as at 1999), an estimate of the extent to which they have been previously cleared, and their vulnerability status.

Table 4-6 Extent of endangered ecological communities within the Mid-North Coast Region of NSW

Endangered ecological community impacted by the Proposal	Corresponding NPWS 1999 vegetation community	Extent in Region in 1999	Cleared estimate for Region	Status in NPWS 1999
Swamp Sclerophyll Forest	Paperbark swamp forest	28,577 ha	75%	Vulnerable Private Land Priority
	Swamp mahogany swamp forest	578 ha	75%	Rare Private Land Priority
Swamp Oak Floodplain Forest	Swamp Oak swamp forest	2883 ha	75%	Rare Severely Depleted Highly Inadequately Reserved Private Land Priority
Subtropical Coastal Floodplain Forest	Cabbage gum open forest or woodland	3002 ha	70%	Vulnerable
	Forest red gum - swamp box	57,016 ha	60%	Severely Depleted Private Land Priority
Freshwater Wetlands	Coastal freshwater meadows, sedgelands, rushlands and forblands of lagoons and wetlands	24,118 ha	40–80%	Endangered Private Land Priority

Note: The extent of Freshwater Wetlands shown may be overestimated as the NPWS Map Unit 141 includes two vegetation communities – forested wetlands and freshwater wetlands. However only the freshwater wetland community strictly corresponds to the EEC.

Table 4-7 shows the area of the EECs proposed to be cleared for the Proposal, and then expresses this as a percentage of the total regional estimate of the extent of the endangered ecological community as existing in 1999.

Table 4-7 Proportion of the total area of endangered ecological communities in the Mid-North Coast Region of NSW affected by the Proposal

Endangered ecological community impacted by the Proposal	Total estimated extent in the Region in 1999	Area impacted by Proposal	Percentage of Regional extent impacted
Swamp Sclerophyll Forest	29,155 ha	19.9 ha	0.07%
Swamp Oak Floodplain Forest	28,833 ha	0.9 ha	0.003%
Subtropical Coastal Floodplain Forest	60,018 ha	11.7 ha	0.02%
Freshwater Wetlands	24,118 ha	3.8 ha	0.02%

Table 4-7 shows that less than 0.1 per cent of the total area of any EEC in the Mid-North Coast Region of NSW (as estimated in 1999) would be removed or modified by the Proposal. The area of each EEC indirectly affected by runoff, weed invasion and other degrading processes may slightly increase these percentages, However, even taking into account additional clearing that may have occurred between 1999 and today, the extent of clearing is not considered to be significant in the overall regional context.

4.15.2 Native vegetation

While there would be impacts associated with the Proposal, the cumulative impacts of the entire Pacific Highway Upgrade Program in the North Coast Bio-Region would include a greater extent of clearing of native vegetation and habitats as well as further fragmentation of habitat. **Table 4-8** shows the extent of native vegetation and endangered ecological community disturbance for recently completed projects, projects under construction, and projects in the planning phase under the Pacific Highway Upgrade Program.

Table 4-8 Extent of native vegetation disturbance associated with the Pacific Highway Upgrade Program

Project	Native vegetation disturbance (hectares)	Endangered ecological community disturbance (hectares)
Projects completed		
Raymond Terrace bypass duplication	5	2
Raymond Terrace to Karuah	37	4
Karuah bypass	36	3
Karuah to Buladelah	123	9
Buladelah to Coolongolook	106	8
Wang Wauk to Bundacree	10	0
Bundacree Creek to Possum Brush	4	1
Coopernook bypass	2	1
Coopernook to Moorland	8	3

Project	Native vegetation disturbance (hectares)	Endangered ecological community disturbance (hectares)
Moorland to Herons Creek	64	5
Lyons to England Road	2	1
Halfway Creek	12	0
Tandy's Lane upgrade	1	1
Brunswick Heads bypass	7	5
Brunswick to Yelgun	49	8
Yelgun to Chinderah	30	12
Sub-total – projects completed	***496 ha***	***63 ha***
Projects recently approved or currently under construction		
Bulahdelah bypass	33	3
Kempsey to Eungai upgrade	286	63
Sapphire to Woolgoolga upgrade	83	18
Wells Crossing to Iluka Road – Glenugie Upgrade	65	5
Ballina bypass	11	9
Tintenbar to Ewingsdale [1]	10	2
Banora Point Upgrade	8	4
Sub-total – projects recently approved or currently under construction	***496 ha***	***104 ha***
Projects in the planning phase		
F3 to Raymond Terrace [2]	49	Assessment to be completed
Oxley Highway to Kempsey (the Proposal) [3]	203	36
Warrell Creek to Urunga upgrade [4]	255	60
Coffs Harbour Bypass [5]	21	Assessment to be completed
Woolgoolga to Wells Crossing [5]	230	51 (preliminary estimate)
Wells Crossing to Iluka Road – remaining [5]	345	55
Iluka Road to Woodburn – remaining [5]	Assessment to be completed	Assessment to be completed
Iluka Road to Woodburn – Devils Pulpit Upgrade [4]	54	12
Woodburn to Ballina [5]	131	56
Sub-total – projects in the planning phase	***1288 ha***	***270 ha***
Total – Pacific Highway Upgrade Program	**2280 ha**	**437 ha**

Note: 1 This project was recently approved and is currently in the detailed design phase.
2 The preferred route has been selected for this project.

3 The environmental assessment is currently being prepared for this project
4 The environmental assessment display has been completed for these projects.
5 The concept design has been finalised for these projects.

As part of the Pacific Highway Upgrade Program, the RTA is mitigating the impacts of vegetation loss from clearing operations by implementing a biodiversity offset strategy. This is in addition to the development of a highway route which avoids or minimises the impacts on sensitive areas of native vegetation where possible.

As part of this biodiversity offset strategy, the RTA purchases land as compensatory habitat, and subsequently transfers ownership of that land to DECCW for ongoing conservation. To date, about 1200 hectares of land has been acquired by the RTA to offset the clearing impacts of the Pacific Highway Upgrade Program. This area of compensatory habitat mainly covers those projects in **Table 4-8** shown as 'projects completed'.

In addition, about 1860 hectares of land is currently proposed as compensatory habitat for native vegetation and endangered ecological community impacts for a number of the projects identified in **Table 4-8** as currently under construction or still in the planning phase. The RTA is continuing consultation with DECCW and DII as appropriate for biodiversity offset packages for the remaining projects that are not covered by the compensatory habitat referred to above.

The actual land exchange ratio agreed with DECCW and DII for the biodiversity offset strategy has varied from project to project over the last 14 years. However, the general land exchange ratio adopted is about 2:1 for native vegetation, and about 4:1 for endangered ecological communities, on a like-for-like basis.

Further to this, the RTA's biodiversity offset strategy also includes revegetation in strategic locations and investment in management research related to the rehabilitation and protection of threatened species.

4.15.3 Fauna

The removal of habitat for the Proposal would add to the cumulative impacts on local fauna populations resulting from development in the area. The local koala population would likely be particularly affected by these cumulative impacts. Apart from the loss of foraging habitat, a major impact on the koala population could be from a potential increase in road fatalities and injuries if mitigation measures are not implemented.

Although the Proposal follows the existing highway for the majority of its route, the wider cleared road easement increases the time that fauna would need to travel across the ground. In areas where the route deviates from the existing highway to pass through forested land, without appropriate mitigation measures an initial increase in vehicle strikes could occur after the work is completed as individual fauna may not be used to traffic movements. However disturbance from construction work may initially deter fauna activity within the road easement.

Provision of fauna underpasses would assist with providing safe passage for fauna between areas of habitat on either side of the new road. Permanent floppy top fencing (see **Section 6.3**) would be installed in appropriate locations to direct fauna to dedicated underpasses and combined culverts where they could cross the road in safety. Fencing would be installed in the vicinity of dedicated crossings and in areas where the road traverses areas of key habitat (for example, state forests) and regional corridors. The location and extent of fauna fencing would be determined at the detailed design phase in consultation with DECCW.

Measures to mitigate impacts on local fauna populations and to reduce the Proposal's contribution to cumulative impacts of development in the area are contained within **Section 6**.

4.16 Key threatening processes

A 'key threatening process' is defined under the TSC Act as "*a threatening process specified in Schedule 3*" of the Act. A 'threatening process' is defined as "*a process that threatens, or may have the capability to threaten the survival or evolutionary development of species, populations or ecological communities*". A number of TSC Act listed key threatening processes are also listed as a key threatening process under the NSW FM Act and/or the Federal EPBC Act.

There are a diverse range of threats to biodiversity operating in the study area and wider region with many directly attributable to historic land uses or current human activities. The draft Northern Rivers Regional Biodiversity Management Plan, National Recovery Plan for the Northern Rivers Region (DECCW 2009) has identified and ranked priority threat categories and activities at a regional level and for four component landscape levels. The study area is contained within the Coastal Plains landscape of the Northern Rivers Region identified in the draft Management Plan.

An assessment of the contribution of the Proposal to key threatening processes identified in State and Federal legislation and corresponding priority threat activities identified for the coastal plains landscape of the Northern Rivers region that are of potential relevance to the Proposal is provided in **Table 4-9**.

Table 4-9 Assessment of the contribution of the Proposal to key threatening processes

Key threatening process	High priority threat activities and rank for coastal plains landscape [1]	Assessment of the Proposal's contribution to key threatening processes
Clearing of native vegetation	Clearing and fragmentation associated with urban development Very high	Based on the Proposal footprint, it is expected that the clearing of approximately 203.1 hectares of native vegetation and an additional area of approximately 18.6 hectares containing scattered trees would be required. Therefore the Proposal is expected to contribute to this key threatening process.
Removal of dead wood and dead trees	Human interference – removal of dead wood and dead trees Medium	While large logs and dead standing trees were generally found to be sparsely scattered throughout the study area, given the extent of clearing required, the Proposal is expected to result in the removal of large amounts of dead wood and dead trees from within the study area, therefore contributing to this key-threatening process. However, dead wood and dead trees removed from the construction footprint are to be collected and distributed in adjoining areas of retained habitat.

Key threatening process	High priority threat activities and rank for coastal plains landscape [1]	Assessment of the Proposal's contribution to key threatening processes
Loss of hollow-bearing trees	-	While hollow-bearing trees were generally noted to be sparsely distributed throughout the study area, some areas contained numerous hollow-bearing trees that could provide good fauna habitat for hollow-reliant species. Those areas noted to contain greater numbers of hollow-bearing trees include sections of Maria River and Ballengarra state forests, though the greatest density of hollow-bearing trees occurs where the Proposal deviates from the existing highway alignment through the northern section of Cairncross State Forest. Given the scale of clearing required, the Proposal is expected to result in the loss of a large number of hollow-bearing trees from within the study area and would therefore contribute to this key threatening process. Nest boxes and artificial bat roosts would be installed in areas of secure habitat adjoining the construction area to provide temporary shelter, roosting and nesting habitat for a range of fauna species displaced by clearing.
Removal of bushrock	-	Given the extent of clearing required, the Proposal is expected to result in the removal of some bushrock therefore contributing to this key-threatening process. However, bushrock removed from the construction footprint would be collected and distributed in adjoining areas of retained habitat.
Human-caused climate change	-	The Environmental Assessment outlines an assessment of the impacts of the Proposal on climate change and an assessment quantifying the greenhouse gases created as result of construction and operation of the Proposal. Embodied emissions in materials have the greatest overall contribution to adding greenhouse gases to the atmosphere and thus subsequent anthropogenic climate change impacts. Emissions arising from vegetation loss and fuel consumption are also reasonably significant while emissions from purchased electricity were estimated to have an immaterial greenhouse impact from the Proposal. A relatively small net reduction in emissions was estimated during operation of the road due to improved fuel efficiency gains from the road upgrade. However the savings are not significant enough to offset the emissions produced during construction.
Alteration to natural flow regimes of rivers and streams and their floodplains and wetlands	Low	This key threatening process could potentially be relevant to the Proposal however these factors could be successfully mitigated by provision of adequate structures to maintain existing water flow, in the form of culverts, bridges, drains etc. In order to avoid contributing to this key threatening process, it is important to maintain current flow, water quality and flooding regimes.

Key threatening process	High priority threat activities and rank for coastal plains landscape [1]	Assessment of the Proposal's contribution to key threatening processes
Degradation of native riparian vegetation along NSW watercourses	-	Riparian habitat is extremely important for terrestrial and aquatic fauna. Whilst the Proposal would clear 7.8 ha of riparian forest, this would be limited to relatively narrow bands at each watercourse. Areas disturbed during the construction process but not required for operation of the road would be revegetated progressively during and following construction.
Instream structures and other mechanisms that alter natural flow regimes of rivers and streams	-	This key threatening process could potentially be relevant to the Proposal at watercourse crossings however these factors could be successfully mitigated by provision of adequate structures to maintain existing water flow, in the form of culverts, bridges, drains etc. In order to avoid contributing to this key threatening process, it is important to maintain current flow, water quality and flooding regimes.
Removal of large woody debris from rivers and streams	-	Woody debris provide important aquatic habitat. The Proposal is unlikely to contribute to this key threatening process as woody debris removed during construction would be redistributed during rehabilitation works.
Ecological consequences of high frequency fire	Inappropriate fire regimes Very high	The Proposal is unlikely to increase the frequency of fire within the study area and therefore would not contribute to this key threatening process.
Predation by the European red fox *Vulpes vulpes*	Very high	The European red fox was recorded within the study during the field surveys. The Proposal is unlikely to increase the threat from this introduced predator.
Predation by the feral cat *Felis catus*	Very high	The cat was recorded within the study area. It is likely that feral cats occur along the length of the study area The Proposal is unlikely to increase the threat from this introduced predator.
Competition and grazing from the feral European rabbit *Oryctolagus cuniculis*	Pests Very low	The Proposal is unlikely to result in an increase in numbers of the feral European rabbit within the study area and therefore would not contribute to this key threatening process.
Competition and habitat degradation from feral goats *Capra hircus*	-	The Proposal is unlikely to result in an increase in numbers of feral goats within or adjacent to the study area and therefore would not contribute to this key threatening process.
Predation, habitat degradation competition and disease transmission by feral pigs *Sus scrofa*	-	Feral pigs were recorded during surveys within the study area. The Proposal is considered unlikely to increase the incidence of this key threatening process.

Key threatening process	High priority threat activities and rank for coastal plains landscape [1]	Assessment of the Proposal's contribution to key threatening processes
Invasion and establishment of the cane toad *Bufo marinus*	Pests High	The cane toad has a patchy distribution in coastal areas of northern NSW and is more common near the Queensland border. An isolated population occurs at Port Macquarie and there is a possibility that this invasive species already occurs within the study area. While the Proposal is not expected to increase cane toad numbers in the area, if a cane toad is found during construction works, the local DECCW office should be contacted immediately. Any suspected cane toads should not be killed as there are a number of native frog species that look very similar (in particular, the threatened giant barred frog). The local DECCW office would be able to correctly identify and dispose of the cane toad humanely.
Competition from feral honeybees *Apis mellifera*	-	The Proposal is unlikely to result in an increase of the feral honeybee within the study area and therefore would not contribute to this key threatening process.
Predation by the plague minnow *Gambusia holbrooki*	-	The plague minnow is considered to be a threatening factor contributing to the decline of the giant barred frog (Fitzgerald 2006). The plague minnow was recorded in Fernbank Creek, Cooperabung Creek, Smiths Creek, Pipers Creek and Maria River (where the giant barred frog was recorded) and is likely to occur elsewhere within the study area. The Proposal is unlikely to increase population numbers of the plague minnow within the study area and is therefore unlikely to contribute to this key threatening process.
Invasion, establishment and spread of lantana *Lantana camara*	Invasion, establishment and spread of lantana Very high	Lantana was found to be common and abundant within the study area and its invasion, establishment and spread would need to be managed during both construction and operation of the Proposal as part of a general weed management strategy to prevent impacts on adjoining retained habitat.
Invasion and establishment of exotic vines and scramblers	Invasion and establishment of exotic vines and scramblers Medium	Particular parts of the study area were found to contain established populations of exotic vines and scramblers. Their invasion and establishment would need to be managed during both construction and operation of the Proposal as part of a general weed management strategy to prevent impacts on adjoining retained habitat.
Invasion of native plant communities by exotic perennial grasses	Weed invasion Very high	Numerous species of exotic perennial grasses were recorded in the study area during field surveys, some of which are highly invasive in natural vegetation communities. Their spread would need to be managed during both construction and operation of the Proposal as part of a general weed management strategy to prevent impacts on adjoining retained habitat.

Key threatening process	High priority threat activities and rank for coastal plains landscape [1]	Assessment of the Proposal's contribution to key threatening processes
Infection of frogs by amphibian chytrid causing the disease chytridiomycosis	Infection of amphibians with chytrid fungus Medium	While it is unlikely that the Proposal would lead to an increase in the incidence of chytridiomycosis in frog populations within the study area, this disease is known to affect the giant barred frog and other threatened frog species with potential to occur within the study area. Chytrid fungus is a water borne pathogen and could be spread through water or mud on vehicles, machinery, footwear and other equipment. In order to prevent the spread of chytrid fungus, appropriate cleaning and disinfection protocols would need to be followed when moving between wet-area work sites (including creek crossings, dams, wetlands and swampy areas) as per *Hygiene protocol for the control of disease in frogs* (NPWS 2001).
Infection of native plants by *Phytophthora cinnamomi*	Dieback caused by *Phytophthora cinnamomi* Low	There is a risk of this fungus being introduced on machinery, clothing and in soil/fill during construction of the Proposal, and specific management measures would be implemented. National Best Practice Guidelines for the management of root rot *Phytophthora cinnamomi* have been produced by the National Heritage Trust (O'Gara *et al*. 2005) .

Notes: 1. Rankings for high priority threat activities operating in the coastal plains landscape of the Northern Rivers Region identified in the draft Northern Rivers Regional Biodiversity Management Plan (DECCW NSW 2009).