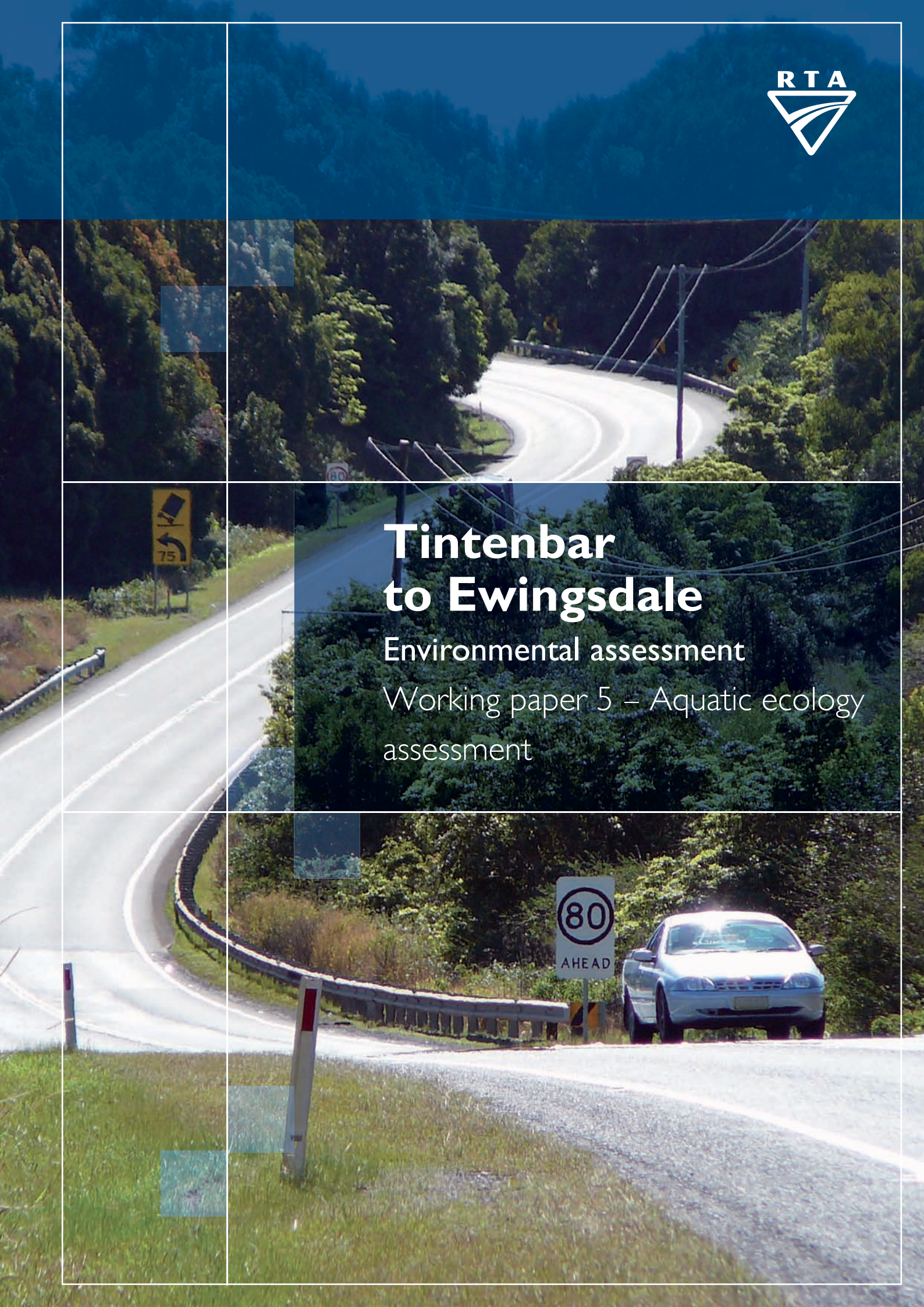


Tintenbar to Ewingsdale

Environmental assessment

Working paper 5 – Aquatic ecology assessment

Report to:

Arup for Roads and Traffic Authority

Aquatic Ecology Assessment
Pacific Highway Upgrade – Tintenbar to Ewingsdale

June 2008

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

Aquatic Ecology Assessment
Pacific Highway Upgrade – Tintenbar to Ewingsdale

June 2008

Report to:

Arup for Roads and Traffic Authority

Report Prepared by:

The Ecology Lab Pty Ltd

4 Green Street

Brookvale, NSW, 2100

Phone: (02) 9907 4440

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This Report provides an assessment of aquatic habitats, biota and water quality for the proposed upgrade for the Pacific Highway upgrade from Tintenbar to Ewingsdale. The report summaries data from background information compiled from aerial photography, data on water quality, aquatic biota, locations of potential acid sulfate soils, and searches of databases containing records of threatened and protected aquatic species that may occur within the investigation area. Water quality was assessed in relation to the protection of aquatic ecosystems, with detailed assessment of impacts on drinking water quality undertaken in other reports. This report summarises the results field investigations undertaken in December 2004, May 2005 and 29 November to 1 December 2006, including new data on physico-chemical water quality and parameters including nutrients, oil and grease, organochlorine pesticides, heavy metals, suspended solids, chloride and sulfate. Assessments were made on the proposed upgrade concept design.

Watercourses were classified according to fish habitat present and type of crossing required to maintain fish passage and aquatic biodiversity. No protected aquatic habitats were present within the investigation area. One protected fish species, eastern freshwater cod, has been stocked by Department of Primary Industries (NSW Fisheries) in Emigrant Creek dam, which lies just outside the investigation area, but there are no confirmed recent records of the species and it is concluded based on recent and historical records that the species is unlikely to be present in watercourses crossed by the proposed upgrade. A small population of a species requiring consideration during planning, freshwater catfish, was found in the outflow of the created wetland to the west of the proposed upgrade.

Previous studies of water quality within the Emigrant Creek catchment indicated that land uses including agriculture and grazing had deleterious impacts on water quality, with many parameters exceeding guidelines for the protection of aquatic ecosystems. Results of water quality sampled *in situ* in the investigation area indicated similar trends, although sampling was done at each site once only, after periods of dry weather. Water quality results for all watercourses were typical of aquatic ecosystems that have been historically highly disturbed by agricultural and grazing practices. There were no detectable organochlorine pesticides or oil and grease residues found in any watercourse. Levels of total phosphorus and total nitrogen exceeded ANZECC guideline trigger values for protection of aquatic ecosystems in Byron, Skinners and Emigrant creeks. Low levels of chromium were present in those waterways but all levels of heavy metals were below guidelines with the exception of copper at one location in Emigrant Creek.

Because the alignment of the proposed upgrade largely lies above the coastal plain, there are no areas identified as having high risk of acid sulfate soils, and hence there is no risk of runoff of acidic water from exposed acid sulfate soils.

The majority of watercourses along the proposed upgrade were small creeks or drainage lines, and crossing these would cause little to no impact on aquatic habitats, water quality, water flow or creek stability. All crossings would be designed to comply with existing policies and guidelines, and as such, natural water flow, fish passage and water quality are likely to improve compared to the existing situation. New bridges would be installed where the proposed upgrade would cross a tributary of Emigrant Creek, Emigrant Creek, Skinners Creek, Bryon and a tributary of Tinderbox Creek. Each crossing would be designed so that bridge runoff is directed to and treated in sediment basins. The net result would be a reduction in pollutants entering the creeks and drinking water catchments.

Although the section of the proposed upgrade near Newrybar would cause resumption of a small area of created wetland where the route crosses a tributary of Emigrant Creek, the impacts would be offset by an improvement in water quality entering the creek downstream of the new and existing bridge crossings.

Replanting riparian vegetation using native species and additional riparian plantings are mitigation measures recommended to compensate for disturbance to riparian vegetation due to construction and shading impacts of bridges. Although outside the scope of this proposal, two improvements to facilitate fish passage are recommended to be undertaken by relevant bodies:

- The upgrade of the existing culvert where Emigrant Creek crosses the Pacific Highway;
- The removal of a causeway upstream of the proposed bridge over Byron Creek.

The proposed upgrade includes the diversion of Tinderbox Creek or its small tributaries in several 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.

1.0 INTRODUCTION

The Ecology Lab Pty Ltd has been commissioned by Arup on behalf of the Roads and Traffic Authority (RTA) to undertake aquatic ecological and water quality investigations of watercourses potentially affected by the proposed Tintenbar to Ewingsdale Pacific Highway upgrade. This Aquatic Ecology Assessment provides impact assessments of proposed upgrade concept design (Figure 1) on aquatic habitats, biota and water quality based on background information, data from field investigations and considerations of mitigative measures incorporated into the concept design.

1.1 Project Description

A brief description of the proposed highway is outlined below.

The length of the proposed upgrade is approximately 17 km starting at Ross Lane in Tintenbar and extending to the north at the existing Ewingsdale interchange, near the settlement of Ewingsdale. Generally the proposed upgrade follows the existing highway corridor from Ross Lane to Bangalow bypass before diverging to the northeast through Tinderbox Valley. From here the proposed upgrade avoids the steep grades of St Helena Hill by way of a tunnel approximately 340 m long and 45 m below the ridge line. North of the tunnel the proposed upgrade alignment is located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

The general features of the proposed upgrade are as follows:

- Four-lane divided carriageways, with a wide median allowing for the addition of a third lane in each direction.
- Class M standard highway with a 110km/h design speed and access control over the full length.
- Full interchanges at Ross Lane and Ewingsdale.
- A half interchange at Ivy Lane. North facing ramps provide access between the local road network and the proposed upgraded highway to the north.
- A half interchange at Bangalow. South facing ramps provide access between the local road network and the proposed upgrade to the south. This arrangement replicates the arrangement with the existing Bangalow bypass.
- A tunnel through St Helena Hill approximately 340m long and 45 m below the ridge line.
- Six twin bridges and four underpasses allowing roads and creeks to pass underneath the proposed upgrade.
- Two bridges carrying local roads over the proposed upgrade.

- At least 1-in-100 year flood immunity.
- Emergency u-turn and median crossovers at about 2.5 km intervals. These facilities incorporate lay bys where vehicles can safely pull off the upgraded highway.
- Sedimentation basins to intercept most run-off for treatment before discharging into the natural watercourses.
- Safe median and outer verges, including safety barriers where required.
- Relatively flat gradients compared to the existing highway.
- Existing highway to be retained for local and regional traffic and as a tourist route.
- Two significant diversions of the existing highway, one just north of Emigrant Creek and the other just south of the Ewingsdale interchange.

As part of the design drainage culverts and sediment basins have been incorporated. This impact assessment considers the impact where they are associated with natural water bodies or water courses.

Note that all sediment ponds within Emigrant Creek drinking water catchment would operate as "wet" water quality basins during construction phase of the proposed upgrade and reconfigured as sand filtration basins during operational phase of the proposed upgrade.

1.2 Methodology and Assumptions

The investigation area for this assessment was defined as any watercourse or wetland (natural or artificial) occurring within 500 m of the centreline of the proposed upgrade (Figure 1). The potential impacts of the proposed highway upgrade on downstream watercourses, wetlands, aquatic habitats, biota and water quality were also considered.

1.2.1 Background Information

The library database of The Ecology Lab containing over 23,000 journal articles from the scientific literature and more than 3,000 books and technical reports specifically on aquatic ecology was searched for relevant material on the aquatic ecology, communities, habitats and water quality within the investigation area. Threatened species listed on the updated schedules of the NSW *Fisheries Management Act* (FM Act) 1994 and *Threatened Species Conservation Act, 1995* (TSC Act), and Commonwealth *Environment Protection and Biodiversity Act, 1999* (EPBC Act) were investigated to assess their likelihood of occurring within the investigation area.

The Department of Primary Industries (NSW Fisheries) 'fishfiles' electronic database was searched for records of threatened and protected species using the Richmond drainage basin search option (Web reference 1). The 'fishfiles' database has since been superseded

by the NSW government BioNet system which allows searches for species records of all NSW government agencies (Web reference 2). The BioNet system was also searched for listed threatened and protected species using the Northern Rivers search option. The most recent searches were done in June 2007.

Adam *et al*. (1985, updated 2002; digital data) was used to locate SEPP 14 wetlands in the vicinity of the investigation area. Maps from Department of Land and Water Conservation (DLWC) Acid Sulfate Soils Risk Mapping project were downloaded from the NSW Natural Resource Atlas (web reference 3) and referred to along the route of the proposed upgrade.

Existing data on water quality for Emigrant Creek and one site on Tinderbox Creek were sourced and reviewed with respect to protection of aquatic ecosystems (WBM Oceanics 1999, SKM 2005).

1.2.2 Field Investigations

Field observations and investigations of aquatic habitats and water quality along the proposed upgrade were made by The Ecology Lab on four occasions:

- 30th of November and the 2nd of December, 2004: Habitat and water quality data recorded.
- 23rd and 26th of May 2005: Habitat and water quality data recorded.
- 22nd to 24th of November 2005: Fish and mobile invertebrate sampling.
- 29 November to 1 December 2006: Inspection of selected water crossings.

Weather conditions preceding each of the field data collection periods was typical for the season in which it was conducted, and no unusual or extreme weather conditions occurred in the three weeks prior to or during field data collections.

The following table indicates the type of data collected for each of the major waterways along the proposed upgrade.

Table 1: Types of Data Collected for major waterways along the proposed upgrade.

Waterway (listed from south to north)	Type of Data Collected				
	Background Information	**Habitat Assessment**	**Waterway Classification**	**Water Quality**	**Fish and Mobile Invertebrates**
Emigrant Creek	✓	✓	✓	Physico-chemical, metals, nutrients	At six sites (including sites on tributaries)
Skinners Creek	✓	✓	✓	Physico-chemical, metals, nutrients	At two sites
Byron Creek	✓	✓	✓	Physico-chemical, metals, nutrients	At two sites
Tinderbox Creek	✓	✓	✓		At two sites

Supplemental observations and habitat assessments were made of minor creeks and drainage lines at sites where they would cross the proposed upgrade.

Habitat Assessment

At each waterway visited assessments were made of water quality, flow and colour and morphological features (substratum, width-depth ratio, bank stability and composition, silt cover, pools, riffles and runs). Characteristics of the riparian zone recorded included instream and riparian vegetation, width, nature (native, exotic, mixture), completeness, and whether or not vegetation overhangs the bank of the waterway. The distribution of snags (if present) and their effect on flow was also assessed. The location of each observation site was recorded using a hand-held GPS unit and the site photographed. The type of any existing crossing was noted and the waterway at the observation point classified using the NSW Guidelines and Policies for fish friendly road crossings (Fairfull and Witheridge 2003). Other features, such as barriers to fish movement, the extent and type of disturbance of each site, other fauna observed and weather were also recorded.

Information from residents regarding aquatic and terrestrial fauna observed in various waterbodies was compiled and considered when assessing value of aquatic habitats.

Water Quality

Physico-chemical water properties were measured included: conductivity (µs/cm), salinity (ppt), temperature (^{o}C), turbidity (ntu), dissolved oxygen (mg/L and % saturation), pH, and ORP (oxidation reduction potential)(mV) were recorded using a YeoKal 611 multiprobe. In addition, water samples were collected from the larger watercourses and dispatched for analytical testing for organochlorine pesticides, trace elements, oil and grease, nitrogen, phosphorus and chloride by the National Measurement Institute.

Fish and Mobile Invertebrate Sampling

Fish and mobile invertebrates (prawns, shrimps) present in waterways along the proposed upgrade were considered good indicators of aquatic health that could be assessed in an efficient and cost effective manner.

Electrofishing, bait trapping and seine netting were used in appropriate habitats to sample fish and mobile invertebrates. These techniques are non-destructive, and all but introduced pest species, including the plague minnow (mosquito fish, *Gambusia holbrooki*) were returned unharmed to the water. Electrofishing was done in Byron Creek and Emigrant Creek and tributaries, bait trapping was done in Tinderbox Creek, Skinners Creek, Emigrant Creek (smaller tributaries). At each location sampled, one site upstream and one site downstream of the proposed upgrade crossing were sampled. Data are presented as the total numbers captured at each site.

Desktop Mapping

Initial identification, mapping and classification of waterways along the proposed upgrade were done based on aerial photographs supplied by RTA. These classifications were subsequently revised based on updated aerial photographs (June 2005), updated hydrology mapping layers, the extent of the footprint of the final proposed upgrade and the results of field investigations.

1.2.3 Assumptions

The assessment of potential impacts of highway upgrade were based on the concept design (Figure 1), including the extent of the upgrade footprint and types of waterway crossings detailed therein. Assessments considered:

- the revised classification of waterways;
- updated review of the potential for threatened aquatic species;

- results of field habitat assessments;
- water quality data; and
- fish and macroinvertebrate sampling.

The assessment of the potential for threatened species to occur in waterways at or near new and existing water crossings was based on updated searches for threatened species (June 2007) in the waterways as listed under the NSW *Fisheries Management Act 1994* (*FM Act*) and *Threatened Species Conservation Act 1995* (*TSC Act*) and Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and the results of field surveys.

Surveys of fish and mobile invertebrates were undertaken once only during spring (November 2005), an appropriate survey time which should reveal the full range of fish and invertebrate species present given the variety of sampling techniques employed. This survey provides no information on potential variations in fish and mobile invertebrate populations through time, rather it presents an appropriate "snapshot" view of fish and mobile macroinvertebrate communities. Sampling techniques focussed on in-stream species and noted but did not target semi aquatic forms such as amphibians, aquatic reptiles, platypus or aquatic birds, and included information on the occurrence of these fauna where it was provided by landowners. Information on amphibians, reptiles, platypus and birds has been incorporated into the Terrestrial Ecology Assessment (Biosis Research 2007). Similarly, data on water quality were collected at one time only and are hence are also "snapshot" in nature, rather than comprehensive, but are supported by data collected previously by others (WBM Oceanics 1999, SKM 2005).

1.3 Policy Context and Legislative Framework

This assessment has included reference to threatened species, and threatening processes listed on the NSW *Fisheries Management Act,* 1994 (*Fisheries Management Amendment Act*, 1997) and the *EPBC Act,* 1999 (Commonwealth).

The *Water Management Act,* 2000 and the *Rivers and Foreshores Improvement Act*, 1948 (NSW) require consideration of environmental issues such as native vegetation in the riparian zone, water quality, construction of instream structures and road crossings which are likely to be relevant in the proposed upgrade.

State Environmental Planning Policy 14 – Coastal Wetlands (SEPP 14) is designed to preserve and protect coastal wetlands by considering developments in terms of

environmental effects. There are a number of SEPP 14 listed wetlands to the east of the proposed upgrade alignment (Figure 2), but none within the footprint of the proposed upgrade.

The classification of waterways was done according to NSW Policy and Guidelines; Aquatic Habitat Management and Fish Conservation (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003).

The assessment of impacts assumed that any waterway crossing would be designed and built to comply with these guidelines and policies.

Fish habitat classifications used to assign waterway type are indicated in the table below. Classifications of waterways near their intersection with the proposed upgrade are indicated in Figure 1.

Table 2: Matching preferred crossing type to waterway type (Source: Fairfull and Witheridge 2003).

Classification	Characteristics of Waterway Type	Minimum Recommended Crossing Type
Class 1 – Major Fish Habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge, arch structure or tunnel.
Class 2 – Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and / or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford.
Class 3 – Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora present).	Culvert, causeway or ford

2.0 EXISTING CONDITIONS

2.1 Consideration of Threatened and Protected Species, Ecological Communities and Key Threatening Processes

2.1.1 Threatened Species

The *Fisheries Management (FM) Act* identifies two threatened freshwater species whose ranges include the watercourses traversed by the proposed upgrade, incorporating the Richmond River drainage basin at the southern end of the proposed upgrade.

These species are the endangered eastern freshwater cod (*Maccullochella ikei*) and oxleyan pygmy perch *(Nannoperca oxleyana*). A search of the DPI 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. Threatened fish species considered below have potential to occur in the waterways within the investigation area or in aquatic habitats downstream of waterways within the investigation area.

Eastern Freshwater Cod

Records exist for the introduction of eastern freshwater cod into Emigrant Creek dam (Faragher *et. al,* 1993). However, recent communication with NSW DPI-Fisheries (Max Enklaar, DPI Fisheries Conservation Officer – Ballina Office, pers. comm.) indicate that eastern freshwater cod are highly unlikely to be present in the dam, or in the reach of the creek immediately downstream of the dam. This conclusion is based on the following considerations:

- The absence of any records of capture of eastern freshwater cod despite extensive commercial and recreational fishing activity within this area.
- Targeted scientific surveys including that undertaken by Bishop (1999 a & b) have not found this species within this system.

The NSW Fishfiles database search identified records for the eastern freshwater cod in the Wilson River system, of which Skinners and Byron Creek are tributaries. The closest record to the investigation area was recorded by the Australian Museum in the early 20th century in the Wilsons River near Nashua. NSW Fisheries records since 2000 show this species in Rocky Creek dam, Coopers Creek and the upper Wilsons River. There has been an unconfirmed report of eastern freshwater cod in Byron Creek near Bangalow (Arup

community consultation: 16 November, 2004, Newrybar Meeting: PT 233). While consideration of eastern freshwater cod is required in assessing the potential impact of the proposed upgrade in the vicinity of Emigrant, Skinners and Byron Creek catchments, it is considered highly unlikely that eastern freshwater cod occur in any waterway that may be affected by the upgrade of the Pacific Highway between Tintenbar and Ewingsdale.

Oxleyan Pygmy Perch

Oxleyan pygmy perch have a restricted and patchy distribution, being found only in low-lying 'wallum' (Banksia dominated) ecosystems. This habitat does not exist in the vicinity of the proposed upgrade. The lack of habitat combined with the absence of records suggests that the oxleyan pygmy perch can not be considered to exist within the vicinity of the proposed upgrade alignment.

Eastern freshwater cod and oxleyan pygmy perch are also listed under the Commonwealth EPBC Act 1999.

Olive Perchlet

The olive perchlet (*Ambassis agassizii*) is listed as an endangered population under Part 2 of Schedule 4 of the FM Act, 1994 in its western range (west of the Great Dividing Range). Records of the eastern population of the olive perchlet have been recorded in the Richmond River including estuarine waters of Emigrant Creek. While this population is not specifically protected it may exist downstream of the proposed upgrade and hence requires consideration.

Silver Perch

Silver perch (*Bidyanus bidyanus*) are currently listed as a vulnerable species in NSW under Part 1 of Schedule 5 of the *Fisheries Management Act, 1994*. This legislative protection is designed to protect the declining population of silver perch in their natural range of the Murray-Darling river system. Silver perch in the investigation area have been stocked in impoundments for recreational fishing and are from artificial breeding programs and genetically distinct from wild stock. Silver perch are bred at the Palm Springs fish hatchery for the aquarium market. Silver perch within the area of the proposed upgrade are not considered as a species requiring special consideration.

Freshwater Catfish

The freshwater catfish (*Tandanus tandanus*) is not listed as a threatened species however it is a species that has shown a decline in numbers in its natural habitat of freshwater watercourses. Through community consultation, a number of watercourses that cross the proposed upgrade that may provide habitat for freshwater catfish have been identified and as such this species and its habitat require consideration.

Marine and Estuarine Species

Marine and estuarine protected species listed under the FM Act 1994 include the endangered grey nurse shark (*Carcharias taurus*) and green sawfish (*Pristis zijsron*) and the vulnerable great white shark (*Carcharodon carcharias*) and black cod (*Epinephelus daemelii*). The great white shark and grey nurse shark inhabit inshore and offshore coastal waters and rarely enter estuaries, and as such are not considered to be at risk from the proposed upgrade.

No records were found for the black cod within the Richmond drainage basin, whose estuarine reaches receive inflow from Emigrant Creek, although this area does contain extensive areas of suitable habitat for juveniles of this species. Any road development in the investigation area would need to consider the potential impact on this species downstream.

No records exist in the fishfiles database for green sawfish in the investigation area, however there are numerous areas of suitable estuarine habitat where sawfish are known to feed on slow-moving, shoaling fish such as mullet as well as molluscs and small crustaceans. Any road development in this area would need to consider the potential impact on this species downstream.

Green sawfish, the grey nurse shark and the great white shark are also listed under the Commonwealth EPBC Act (1999).

Fish sampling (Table 3) resulted in the capture of no threatened species. One species requiring consideration during planning, freshwater catfish, was found in small numbers at one location in a tributary of Emigrant Creek, the outflow of the created wetland located immediately to the west of the existing Pacific Highway.

2.1.2 Key Threatening Processes

Key threatening processes listed under the FM Act (1994) relevant to the proposed upgrade that require consideration include:

- The removal of large woody debris,
- The degradation of native vegetation along New South Wales water courses,
- The installation of instream structures (i.e. bridges and culverts) and other mechanisms that alter natural flow regimes of rivers and streams,
- Predation by the plague minnow (Mosquito fish) (*Gambusia holbrooki*).

2.2 Aquatic Habitats

Descriptions of aquatic habitats along or near the proposed upgrade as observed during three site inspections (30 November to 2 December 2004, 23 to 26 May 2005 and 29 November to 1 December 2006) are detailed below progressing from the southern most waterway along the route. The distribution and risk classification of acid sulfate soils near the proposed upgrade are shown in Figure 3. Results of fish and mobile macroinvertebrate sampling are based on investigations done on 22 to 24 November, 2005 (Table 3). Figure 4 identifies fish and mobile invertebrate sampling locations along or near the proposed upgrade.

2.2.1 Tributary of Emigrant Creek

The proposed upgrade would approach a tributary of Emigrant Creek on the western side of the existing Pacific Highway, north of Ross Lane (chainage 135600), but would not cross it. The foot of the proposed batter would be located within approximately 20 m of the creek, with potential for movement of sediment into the creek at this point. The unnamed creek was classified as a Class 3 watercourse at this point, and considered as presenting negligible constraints to highway upgrading. A small wetland has been created on this unnamed creek by the damming effect of a small weir/causeway. This wetland has been heavily impacted due to bank erosion from cattle access. Water was very turbid and with a prominent iron flocculant present. Aquatic macrophytes (lilies, grasses and knotweed) were dense within the watercourse. Water level within this wetland appeared to have recently fallen as indicated by the presence of aquatic plants above the observed water level (Observation recorded 29 November to 2 December 2006).

No water quality data are available for this unnamed creek. The existing degraded condition of the wetland limits its aquatic ecological value, however its position in close proximity to remnant native rainforest, and the presence of a small waterfall upstream could provide potential for aquatic rehabilitation and environmental improvement. This small watercourse

flows into Emigrant Creek downstream of Emigrant Creek dam, and as such does not constitute a potential source of contamination for the local drinking water supply.

2.2.2 Emigrant Creek and Tributaries

Emigrant Creek is entirely fresh water above the bridge at Tintenbar and thus is without estuarine influence along the alignment of the proposed upgrade. The major feature is Emigrant Creek dam. During the May 2005 site investigation, the dam level was very low (almost empty) due to maintenance operations, and provided only a fraction of the fish habitat that would be available when at operational capacity. The dam is an effective barrier to fish passage up and downstream. Downstream of the dam Emigrant Creek is graded Class 2 (moderate fish habitat) and includes a reach of approximately 1 km which lies adjacent to the proposed upgrade. Emigrant Creek Dam and approximately 2 km of the creek upstream are graded Class 1 (major fish habitat) when the dam is actively holding water. This reach of Emigrant Creek is located outside of the investigation area, although the western edge of the area is adjacent to the dam.

The upstream reaches of Emigrant Creek and its tributaries along the proposed upgrade are graded Class 2, 3 and 4 fish habitat. Areas of moderate fish habitat include the main channel of Emigrant Creek, downstream of the existing highway crossing (Plate 1 upper). In this reach of the creek there are numerous deep pools providing refuge for fish during extended periods of low flow. There is important variability in the instream habitat including sections of rapid shallow flow, aquatic plant beds, riparian vegetation and snags. The upper reaches of Emigrant Creek and its numerous unnamed tributaries provide mainly minimal to unlikely fish habitat (Plate 1, lower). These watercourses are heavily influenced by extensive agriculture and grazing land use in the area (Plate 2 upper). Much of the riparian vegetation has been cleared, flow has been restricted by numerous farm dams (Plate 2 lower), and numerous causeways and culverts have created barriers to fish passage into upstream areas. Some of the larger farm dams in the catchment are likely to provide habitat for some species, such as silver perch which have been stocked for recreational fishing.

Fish sampling in Emigrant Creek where the existing Pacific Highway crosses the creek (Table 3:Site 8, Figure 4) resulted in only two fish species being collected, with 11 out of 12 fish collected being the introduced mosquito fish (*Gambusia holbrooki*), indicating a marginal and disturbed fish habitat. The other species collected was a single Duboulay's rainbowfish (*Melanotaenia duboulayi)*. The existing crossing does not comply with current guidelines for fish friendly road crossings (Fairfull and Witheridge 2003).

Fish were sampled in a tributary of Emigrant Creek to the west of where the existing Pacific Highway and a new bridge cross the creek, east of the created wetland (Table 3: Site 9, Figure 4). Freshwater catfish, flathead gudgeon, empire gudgeon and mosquito fish were collected using electrofishing and bait trapping techniques at these sites (Table 3, Figure 4). Two turtles were also observed.

Fish sampling in a small tributary of Emigrant Creek west of the existing highway and near the proposed upgrade (Site 11, Figure 4) yielded no fish. In the main channel of Emigrant Creek, west of where the proposed upgrade would run in parallel to Emigrant Creek (Site 10, Figure 4) longfinned eels, striped and empire gudgeons, prawns, yabbies, crayfish and shrimp were captured (Table 3).

2.2.3 Skinners Creek

Skinners Creek is a tributary of the Wilsons River which flows through Lismore and joins the Richmond River estuary at Coraki. The upper reaches of Skinners Creek and its tributaries that lie within the investigation area are all graded Class 3 and 4 fish habitat. The main channel of Skinners Creek flows through a valley in which grazing and agriculture are the dominant land uses (Plate 3). There is minimal riparian vegetation along the watercourse. Areas of permanent wetland habitat occur along the watercourse and are thickly vegetated with aquatic plants. The dominant fish habitat was aquatic macrophyte beds, with limited deep (1 -2 m) permanent pools, and few snags which provide habitat for native fish. Little to no riffle habitat was present. The existing Pacific Highway crossing of Skinners Creek consists of an eight-pipe (2 m diameter) culvert that creates barriers to fish passage.

Fish were sampled in Skinners Creek where it crosses the existing Pacific Highway, upstream and downstream of the existing pipe culvert (Site 6, Figure 4). This site is in the vicinity of the proposed upgrade option (Figure 4). Four species were collected at this location, with the dominant species being Douboulay's rainbowfish (*Melanotaenia douboulayi)*(Table 3). No introduced mosquito fish (*Gambusia holbrooki)* or mobile macroinvertebrates were present.

2.2.4 Byron Creek

Byron Creek flows westward from the investigation area and joins the Wilson River near Nashua. Byron Creek and its tributary Tinderbox Creek contain reaches that are graded Class 2 (moderate fish habitat) within the investigation area. The largest continuous reach of Byron Creek in the investigation area with moderate fish habitat occurs upstream of

Bangalow to the Rankins Dip causeway, and incorporates the lower reaches of Tinderbox Creek (Plate 4). Riparian vegetation is extensive and largely continuous. Road crossings in this area are the Pacific Highway (Bangalow bypass) and Bangalow Road. Both of these crossings are bridges that do not create barriers to fish passage and have minimal effect on instream habitat and flow characteristics. This reach contains areas of deep pool and riffle habitat, and there are numerous snags, aquatic macrophytes and overhanging bank vegetation providing a variety of fish habitats.

Fish and mobile invertebrate sampling was done in the lower Byron Creek catchment, downstream of the inflow of Tinderbox Creek (Site 1, Figure 4). This reach of Byron Creek was classified as having potential fish habitat and sampling was done upstream and downstream of the proposed upgrade crossing. A total of six species of fish, four species of freshwater crustaceans (prawns and yabbies) and turtles were observed (Table 3: Site 1). No introduced mosquito fish (*Gambusia holbrooki*) were collected. These results indicate that this reach of the creek provides moderate to good habitat for fish and mobile macroinvertebrates.

The upper catchment of Byron Creek is graded Class 3 and 4 fish habitat. The majority of the land has been cleared for grazing and agriculture and much of the riparian vegetation has been removed. There are a number of springs in the steep slopes of the upper catchment that may create small areas of permanent habitat for some species. Farm dams, causeways and culverts have altered stream flow and created barriers to fish passage throughout the Byron Creek catchment within the investigation area.

Fish were sampled in the upper reaches of Byron Creek during the route selection phase of the project (tunnel approaches from the east) (Table 3:Site 2, Figure 4). One of the sampling sites was downstream of a causeway across Byron Creek. At this site, five species of fish were sampled, four species of mobile macroinvertebrates were present and turtles were observed (Table 3: Site 2). At a second site approximately 500 m upstream of the causeway, no fish or mobile invertebrates were caught, indicating that the causeway was an effective barrier to upstream fish passage.

2.2.5 Tinderbox Creek and Tributaries

Tinderbox Creek is a tributary of Byron Creek and contains reaches within the investigation area that are graded Class 2 to 3 (moderate to minimal fish habitat). The majority of the catchment within the investigation area has been cleared for grazing and the creek has minimal riparian vegetation, particularly along its smaller tributaries and drainage lines.

A total of six species of fish were sampled in Tinderbox Creek, upstream of the junction with Byron Creek (Table 3: Site 3, Figure 4). The introduced mosquito fish (*Gambusia holbrooki*) was present, but was as abundant as empire gudgeon (*Hypseleotris compressa*) and Duboulay's rainbowfish (*Melanotaenia duboulayi*). No mobile macroinvertebrates were collected.

Fish were sampled further upstream in Tinderbox Creek where the tunnel approach would make multiple crossings of the creek (Table 3:Site 4, Figure 4). Only four fish species were collected with the dominant species being Duboulay's rainbowfish (*Melanotaenia duboulayi*) (Table 3). No mobile macroinvertebrates were collected.

2.2.6 Simpsons and Tyagarah Creeks

The northernmost section of the investigation area near Ewingsdale contains watercourses above the tidal influence that drain to the Brunswick River estuary via Simpsons Creek and Tyagarah Creek. They provide minimal to unlikely (Class 3 - 4) freshwater fish habitat having been degraded by agricultural and urban development. Simpsons Creek north of the investigation area is the location of the Brunswick Heads sewage outfall. Downstream of the investigation area, Simpsons Creek and the Brunswick River estuary contain extensive areas of mangroves and SEPP 14 wetlands (Figure 2), and support commercial fisheries and oyster farming.

Fish and mobile invertebrates were not sampled in this catchment as the tunnel exit and junction into the Ewingsdale interchange would not cross major creeks in the Simpsons Creek catchment (Figure 4).

Table 3: Fish and mobile macroinvertebrates sampled at waterways within the investigation area. Sampling done 22 to 24, November, 2005 by The Ecology Lab. See Figure 4 for map of sampling locations.

Sampling methods: EF = electrofishing, BT = Bait trapping, SN = Seine netting. Data are totals numbers caught in replicate bait traps (6), electrofishing (5 second shots) or seine net shots.

	Watercourse	**Byron Ck**		**Tinderbox Ck**		**Skinners Ck**
	The Ecology Lab Site No.	1	2	3	4	6
	Sampling Method	EF	EF	BT	BT	BT
Common name	*Scientific name*					
Fish						
Longfinned Eel	*Anguilla reinhardtii*	1	1			2
Freshwater Catfish	*Tandanus tandanus*	4	3			
Flathead Gudgeon	*Philypnodon grandiceps*	12	1	1	1	
Striped Gudgeon	*Gobiomorphus australis*	1		1		
Empire Gudgeon	*Hypseleotris compressa*			24		
Firetail Gudgeon	*Hypseleotris galii*					35
Mosquito Fish	*Gambusia holbrooki*			29	10	
Duboulay's Rainbowfish	*Melanotaenia duboulayi*	2	4	23	128	220
Olive Perchlet	*Ambassis agassizii*			6	4	7
Australian Smelt	*Retropinna semoni*	11	15			
Crustaceans						
Freshwater Prawn	*Macrobrachium* sp.	present	present			
Yabby	*Cherax destructor*	present	present			
Freshwater Crayfish	*Euastacus* sp.	present	present			
Freshwater shrimp	Family: Atyidae	present	present			
Turtles	*Chelodina* sp., *Emydura* sp.	present	present			
Notes		no fish upstream of weir				

Table 3, continued: Fish and mobile macroinvertebrates sampled at waterways within the investigation area. Sampling done 22 to 24, November, 2005 by The Ecology Lab. See Figure 4 for map of sampling locations.

Sampling methods: EF = electrofishing, BT = Bait trapping, SN = Seine netting. Data are totals numbers caught in replicate bait traps (6), electrofishing (5 second shots) or seine net shots.

	Watercourse	**Emigrant Ck**		**Emigrant Ck**		**Tributary Emigrant Ck**
	The Ecology Lab Site No.	8	9	9	10	11
	Sampling Method	BT	EF	BT	EF	BT
Common name	Scientific name					
Fish						
Longfinned Eel	*Anguilla reinhardtii*				16	
Freshwater Catfish	*Tandanus tandanus*		3			
Flathead Gudgeon	*Philypnodon grandiceps*		10	3		
Striped Gudgeon	*Gobiomorphus australis*				8	
Empire Gudgeon	*Hypseleotris compressa*		2	2	1	
Firetail Gudgeon	*Hypseleotris galii*					
Mosquito Fish	*Gambusia holbrooki*	11	21	2		
Duboulay's Rainbowfish	*Melanotaenia duboulayi*	1				
Olive Perchlet	*Ambassis agassizii*					
Australian Smelt	*Retropinna semoni*					
Crustaceans						
Freshwater Prawn	*Macrobrachium* sp.		present	present	present	
Yabby	*Cherax destructor*		present	present	present	
Freshwater Crayfish	*Euastacus* sp.		present	present	present	
Freshwater shrimp	*Family: Atyidae*		present	present	present	
Turtles	*Chelodina* sp., *Emydura* sp.		present	present		

2.3 Acid Sulfate Soils

Acid sulfate soils (ASS) are of potential concern for aquatic ecology in the consideration of the eastern portion of the investigation area of the proposed upgrade. Acid sulfate soils are widespread in NSW estuarine floodplains and coastal lowlands (including mangrove tidal flats, salt marshes and tea-tree swamps). Before drainage and oxidation, they are termed potential ASS. Actual ASS are formed when the naturally occurring iron sulfides (pyrite) in the soil become exposed to air (through drainage or excavation) and subsequently oxidise, forming sulfuric acid.

Observed impacts on the aquatic ecology resulting from ASS include: habitat degradation, fish kills, outbreaks of fish disease, reduced aquatic food resources, reduced migration potential of fish, reduced fish recruitment, altered water plant communities, weed invasion by acid-tolerant plants, and secondary water quality changes. Other potential impacts include the release of heavy metals from contaminated sediments, human and animal health impacts from polluted water, adverse impacts on land arability, and damage to built structures such as bridges (web reference 3)

Maps from the Department of Land and Water Conservation ASS Risk Mapping project identified large tracts of low risk areas in all low lying areas to the east of the investigation area (Figure 2). There are no mapped areas of low risk of ASS within the immediate investigation area (defined as within 500 m of the centreline of the proposed upgrade), although the closest mapped low risk area in the southern portion lies just outside that distance.

Any development in areas with ASS risk requires extensive consideration of potential impacts on the aquatic ecology both in the area and in downstream environments. The potential for impacts on aquatic ecology due to the disturbance of acid sulfate soils was considered in the classification of constraints for all waterways in the investigation area.

2.4 Water Quality

Previous data on water quality with respect to protection of aquatic ecosystems is relevant to only some sections of the investigation area (WBM Oceanics 1999, SKM 2005). Of the locations monitored during wet and dry conditions as part of the Bangalow to St Helena upgrade investigation, only one site in Tinderbox Creek lies within the present investigation area. In both sampling periods, dissolved oxygen, pH and salinity fell within the ANZECC guideline trigger values for protection of ecosystem health. No analysis of contaminants was undertaken (WBM Oceanics 1999).

Twelve monitoring sites were sampled in the Emigrant Creek catchment between September 2003 and May 2005 (SKM 2005). Physico-chemical properties measured *in situ* included nutrients, chlorophyll *a*, *E. coli*, dissolved oxygen, conductivity, temperature, pH and turbidity. A subset of samples were analysed for pesticide content (these results are not currently available). Nutrient levels (ammonia, total nitrogen, total phosphorus, and nitrate) were generally higher during wet sampling events, exceeding ANZECC (2000) guidelines for protection of aquatic ecosystems at most sites sampled. These exceedances indicate that land uses and poor riparian cover are contributing to poor water quality to varying degrees throughout the catchment. Emigrant Creek dam had elevated levels of chlorophyll *a* and algal blooms have previously been observed within the dam. *E. coli* counts consistently exceeded ANZECC guidelines for primary recreation, with large exceedances during wet weather sampling. For both dry and wet weather sampling events, levels of dissolved oxygen were lower than ANZECC guidelines for the protection of aquatic ecosystems at most sites sampled. Lowest values were recorded in upstream reaches of Emigrant Creek. pH values were lower than ANZECC (2000) trigger levels at most sites and during both wet and dry sampling events. This was attributed to increased vegetation or organic matter fertilisers entering watercourses via runoff during rain events (SKM 2005). Overall, the results of this investigation over a two year period (and representing wet and dry conditions) indicate that current land uses, particularly agriculture and grazing, have deleterious impacts on water quality in the Emigrant Creek catchment. Given that land uses are similar throughout the investigation area (although the dominant land use varies between catchments), similar results could be expected in other watercourses in other catchments.

The results of water quality analysis collected during site inspections at the same sites where fish were sampled were used to assess water quality within the investigation area in terms of health of aquatic ecosystems by comparison with ANZECC (2000) guidelines for lowland watercourses in south–eastern Australia. The relevant ANZECC guidelines present

trigger values and ranges for physical and chemical parameters within slightly disturbed lowland watercourses. If values recorded *in situ* lie outside the trigger ranges, then further investigation is warranted with respect to the ability of the watercourse to maintain aquatic health. The water quality data collected represent a "snapshot" view of water quality on the day sampled. Table 4 presents a summary of the comparison of physico-chemical properties measured *in situ* to the relevant ANZECC guidelines for three catchments. Data used to prepare this summary are presented in Appendix 1.

Table 4: Water quality measured *in situ* in the investigation area in comparison with ANZECC (2000) guidelines for slightly disturbed lowland watercourses in south – east Australia. ↓= below trigger value, ↑= above trigger value, V = some values above trigger values, some below, ✓ = within range of trigger values. Comparisons summarised for the reach of watercourse within the investigation area.

	ANZECC trigger value (lowland watercourses)	Emigrant Creek	Skinners Creek	Byron Creek
pH	6.5-8.5	↓	↓	✓
Dissolved Oxygen (% saturation)	90-110	V	↓	V
Salinity (µS/cm)	125-2200	✓	↓	✓
Turbidity	6-50	↓	↓	↓

Causes of the low pH (acidic) water in all waterways except Byron Creek are unknown, but could be due to a range of factors including large loads of organic matter. Although low pH can be a toxic stressor on aquatic biota, the levels present in most watercourses fell just below the trigger value. Effects of this stressor on aquatic biota could be estimated if further studies on ecosystem components such as macroinvertebrates are undertaken after determination of the proposed upgrade, as aquatic macroinvertebrates abundance and diversity are good indicators of ecosystem health.

Levels of dissolved oxygen varied considerably with low levels compared to guidelines recorded at Skinners Creek. These values may be indicative of high instream organic loads, but further data would be required to establish this, as dissolved oxygen levels vary on a daily basis. Values for salinity were variable, with most differences from the default trigger range due to lower salinity levels. These results may have indicated small variations in rainfall prior to the sampling dates.

Water quality samples were also analysed for organochlorine pesticides, oil and grease, heavy metals, chloride, sulfate and nutrient content. No detectable organochlorine pesticides or oil and grease residues were found in any watercourse. All levels of heavy metals detected were below ANZECC guideline trigger values except for copper for one sample in Emigrant Creek.

Table 5 presents a summary of results with comparisons to the relevant ANZECC guidelines. Data used to prepare the summary are presented in Appendix 2.

Table 5: Summary of results of laboratory water quality analyses in the investigation area in comparison with ANZECC (2000) guidelines for the protection of aquatic ecosystems for slightly disturbed lowland watercourses (<150 m elevation) in south – east Australia. NG = No guideline. ↓= below trigger value, ↑= above trigger value, V = some values above trigger values, some below, ✓ = within range of trigger values. Comparisons summarised for the reach of watercourse within the investigation area.

	ANZECC trigger value (lowland watercourse)	Emigrant Creek	Skinners Creek	Byron Creek
Organochlorine Pesticides	**various**	**↓**	**↓**	**↓**
Arsenic	**0.05 mg/L**	**↓**	**↓**	**↓**
Cadmium	**0.002 mg/L**	**↓**	**↓**	**↓**
Chromium	**0.05 mg/L**	**↓**	**↓**	**↓**
Copper	**0.005 mg/L**	**V**	**↓**	**↓**
Lead	**0.005 mg/L**	**↓**	**↓**	**↓**
Mercury	**0.0001 mg/L**	**↓**	**↓**	**↓**
Zinc	**0.05 mg/L**	**↓**	**↓**	**↓**
Chloride	**3 mg/L**	**↑**	**↑**	**↑**
Oil & Grease	**mg/L - NG**	**0**	**0**	**0**
Sulfate	**mg/L - NG**	**6.3**	**1.35**	**3.1**
Suspended Solids	**mg/L - NG**	**11**	**42.75**	**3.5**
Total Phosphorus	**0.05 mg/L**	**↑**	**↑**	**↑**
Total Kjeldahl Nitrogen	**mg/L - NG**	**0.65**	**0.61**	**0.66**
Oxides of Nitrogen	**0.040 mg/L**	**↑**	**↑**	**↑**
Total Nitrogen	**0.50 mg/L**	**↑**	**↑**	**↑**

Overall, water quality results for all watercourses were typical of aquatic ecosystems that have been historically highly disturbed by agricultural and grazing practices. The potential sources of levels of chloride above trigger values are unknown. Elevated levels of nutrients

(total phosphorus, oxides of nitrogen and total nitrogen) are likely to the result of runoff from improved pasture and or agricultural lands. Results obtained represent a once-only snapshot of water quality sampled during a dry period, and hence must be considered indicative only, but agree in general with water quality results for the Emigrant Creek catchment (SKM 2005).

3.0 POTENTIAL IMPACTS ON AQUATIC ECOLOGY

Table 6 summarises potential impacts on aquatic habitats and ecology as a result of the proposed upgrade and planned mitigation measures. Watercourses are listed from south to north.

Table 6: Summary of potential impacts on aquatic ecology and mitigation measures.

Catchment/Watercourse	Potential Impact	Mitigation Measures
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.	Batter fitted with toe drain directed to sediment basin.
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).	Culverts installed at levels that will allow fish passage; none
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.	Culverts installed at levels that will allow fish passage; none
Emigrant Creek/Tributary of Emigrant Creek	New bridge crossing would shade approximately 30 m of creek line.	Bridge footings constructed away from banks and below ground level to minimise impacts, sediment basins to treat highway run off.
Emigrant Creek/Emigrant Creek	New bridge crossing to west of existing Pacific Highway bridge would shade60 m of creek line.	Bridge footings constructed away from banks and below ground level to minimise impacts, sediment basins to treat highway run off.
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	Bridge footings constructed away from banks and below ground level to minimise impacts, sediment basins to treat highway run off.
Bryon Creek/Bryon Creek	Reduction in natural habitats where creek is diverted beneath upgrade footprint via culverts; new bridge crossing upstream east of the	Culverts installed at levels that will allow fish passage; bridge footings

	existing would shade 43 m of creek line,	constructed away from banks and below ground level to minimise impacts, sediment basins to treat highway run off.
Tinderbox Creek/Tributary of Tinderbox Creek and Tinderbox Creek	New bridge crossing would shade 38 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	Bridge footings constructed away from banks and below ground level to minimise impacts, bridge option minimises loss of riparian vegetation; scour reduction included in design where required
Simpson Creek/Tributaries of Simpsons Creek	Reduction in natural creek habitat due to installation of culverts on minor creek lines	None

4.0 ASSESSMENT OF IMPACTS AND MITIGATION MEASURES

4.1 Threatened Species and Ecological Communities

No threatened species listed on the schedules of NSW *Fisheries Management Act* (FM Act)*1994*, the *Threatened Species Conservation Act* (TSC Act)*1995* or Commonwealth *Environment Protection and Biodiversity Act* (EPBC Act) *1999* were considered to be present in waterways in the vicinity of crossings of the proposed upgrade, nor were any captured during fish sampling. One fish species, freshwater catfish, was found in small numbers in a tributary of Emigrant Creek in the outflow of the wetland created within a tributary of Emigrant Creek. Freshwater catfish are not threatened species, but require consideration during planning due to decreases in their populations, particularly populations in flowing watercourses (in contrast to those in dams and lakes). The proposed upgrade at the crossing of this dammed tributary of Emigrant Creek represents no greater risk to the population of freshwater catfish than the existing crossing of the Pacific Highway. In fact, the new bridge structure is likely to improve water quality for catfish by treating runoff of potential contaminants from the bridge surface in sediment ponds prior to drainage into the creek.

No threatened aquatic ecological communities listed under the above mentioned Acts were identified along the alignment of the proposed upgrade.

4.2 Key Threatening Processes

Threatening processes listed under the *FM Act* (1994) relevant to the proposed upgrade that require consideration include:

- The removal of large woody debris,
- The degradation of native vegetation along New South Wales water courses,
- The installation of instream structures (i.e. bridges and culverts) and other mechanisms that alter natural flow regimes of rivers and streams,
- Predation by the plague minnow (Mosquito fish) (*Gambusia holbrooki*).

All relevant key threatening processes have either occurred or are occurring in and along watercourses in the investigation area. The proposed upgrade would avoid increasing the frequency or intensity of key threatening processes listed above as crossings have been designed to comply 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). These guidelines include requirements for:

- Crossing structures appropriate for the size and type of watercourse,
- Maintenance of fish passage throughout construction,
- Preservation of spawning grounds,
- Minimisation of disturbance to and removal of snags,
- Optimal crossing designs to maintain flow,
- Habitat rehabilitation, and
- Sediment control.

Key mitigation measures during the construction of the proposed upgrade would include measures to:

- Maintain fish passage throughout construction (i.e. avoid total blockage of waterway at any one time),
- Preserve spawning grounds (i.e. retain instream and bed features such as gravel beds and snags),
- Minimise disturbance to and removal of snags,
- Control sediment (i.e. bunds around excavated sediment, use wet sediment basins), and
- Rehabilitation of fish and riparian habitats impacted by construction.

Specific responses to potential key threatening processes due to construction and operation of the propose upgrade are detailed below.

Removal of Large Woody Debris

No removal of large woody debris would be required for the construction of waterway crossings for the proposed upgrade, but large woody debris has been removed from waterways in the past. The installation of some culverts may require the removal of smaller woody debris accumulated against some existing structures. Their removal would ensure that the culverts operate as designed, i.e. that they would maintain natural flow regimes and facilitate fish passage. Should removal of large woody debris be required to install new

culverts, it would be relocated within the same creek in a location to ensure it would not become dislodged during high flows and block the culvert.

Degradation of Native Vegetation Along Watercourses

Some native vegetation would be removed to allow the installation of bridge abutments and subterranean footings for bridge piles. Proposed bridge crossings of Emigrant Creek and tributary, Skinners, Byron Creek and tributary of Tinderbox Creek have been designed to be aligned as perpendicular as possible to the respective waterways, reducing potential losses of riparian vegetation on creek banks while allowing for access roads and sediment basins to treat runoff from bridge surfaces.

Replanting disturbed riparian areas after construction would be done using local native species, augmenting previous revegetation of the riparian corridor that has been done in a few locations. Areas for revegetation in the riparian vegetation within land owned by RTA would be undertaken in consultation with local Landcare groups and Rous Water's Healthy Catchment Program managers.

The Installation of Instream structures (i.e. bridges and culverts) and Other Mechanisms that Alter Natural Flow Regimes of Rivers and Streams

The majority of instream structures to be installed along the proposed upgrade would maintain the natural flow regimes of creeks, with new structures representing improvements to structures on the existing Pacific Highway with respect to maintenance of natural flows and facilitation of fish passage. Although outside the scope of this proposal, it is recommended that the existing culvert under the Pacific Highway (chainage 140900) be upgraded to comply with current guidelines, as the compliance of the proposed upgrade crossing immediately downstream would be futile because the existing structure upstream blocks fish passage or alters natural flows. Similarly, the existing Pacific Highway crossing of Skinners Creek should be upgraded to facilitate passage upstream at the new bridge for the proposed upgrade. A recommended mitigation measure within Bryon Creek is the removal of causeway upstream of the new bridge that would facilitate fish passage in the upstream sections of the creek (east of chainage 146900, south of Bangalow Road).

Some culverts in the northern section of the investigation area would alter natural flow paths by shortening and culverting meandering reaches that lie beneath the footprint of the proposed upgrade. Diversions are mainly located in the Tinderbox Creek catchment near the headwaters or in upper reaches of drainage lines that provide minimal fish habitat, and would shorten creek habitat lines by a total of approximately 140 m within the Tinderbox

Creek catchment. The individually short reductions in flow path are unlikely to significantly alter natural flow volume. Where appropriate, the design of the outflow point of culverted water back into the natural creek bed would include scour reduction features. Where overland creek diversions are required, the diversion path would be designed to conform to natural land contours and mimic existing creek bed morphology and hence have little potential to cause ongoing erosion and turbidity.

Predation by the Plague Minnow (Mosquito fish) (Gambusia holbrooki)

The presence of mosquito fish in all waterways except Byron and Skinners Creeks has been confirmed, and although the specie's abundance and distribution is variable, it can be concluded that predation of native fish and invertebrates by mosquito fish occurs. Because mosquito fish proliferate in disturbed aquatic habitats, construction of the proposed upgrade would avoid increasing populations of mosquito fish by avoiding disturbance to creek banks and beds and maintenance of water quality during highway construction and operation (web reference 4). The proposed upgrade would avoid exacerbating the existing predation by mosquito fish by incorporating current best practice design features and construction methodologies that include locating crossing support structures outside the wetted area of the creek, avoiding construction within creek banks, bunding sediments near creeks during construction and inclusion of appropriate runoff control structures (pipes, culverts, sediment basins, sand filtration treatment) where required.

4.2 Acid Sulfate Soils

The alignment of the proposed upgrade is entirely above the coastal lowlands, and consequently no areas where the proposed upgrade would cross watercourses were identified as having potential for disturbance of acid sulfate soils. While industry standard measures to bund and control runoff from disturbed sediments near waterways would be undertaken as part of current best practices that guide this project, no treatment of excavated soils to reduce acidity or to prevent acidic runoff is expected to be necessary.

4.3 Water Quality

The construction of roads can potentially impact on the water quality, sediment quality and biota of waterways by introducing sediment and contaminants (e.g. Krein and Schorer 2000, Perdikaki and Mason 1999, McNeill and Olley 1998, Ellis *et al*. 1997, Maltby *et al*. 1995a, 1995b, Boxall *et al* 1995, 1997, Lund *et al*. 1991, Richardson 1985).

Results of previous water quality assessments and sampling for this investigation indicated that all watercourses along the proposed upgrade have been historically highly disturbed by agriculture and grazing practices. Human access to Emigrant Creek Dam, cattle crossing, recreational uses and road runoff are identified as processes that reduce the water quality and ecosystem health in the investigation area (Ballina Shire Council 2004). The alignment of the proposed upgrade has taken into consideration design factors that would reduce risks to water quality and habitat degradation. These include:

- minimising the number of waterway crossings in total,
- minimising the disturbance of riparian vegetation by locating bridge footings below ground and away from creek bed and banks, and
- maximising the use and design of sediment basin to treat run off from the proposed upgrade;
- designing creek diversions to maintain natural discharge volumes, conform to existing land contours and mimic existing creek levels and profiles.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The proposed upgrade was developed considering the values of safety and functionality, social and economic factors and other natural and environmental factors, including the aquatic ecology and drinking water assessments. Given this, the alignment of each individual section of the proposed upgrade may not represent the optimisation of individual considerations such as aquatic ecology and drinking water quality.

Overall, the proposed upgrade has been designed to the extent possible to avoid or minimise impacts on aquatic habitats, biota and drinking water. It would result in an improvement of water quality overall, largely through the efficient design and use of sediment basins at key locations which would allow an overall reduction the suspended sediment, nutrients loads and other pollutants currently entering the catchment, or reduce the risk of them entering the catchment.

The proposed upgrade is unlikely to negatively impact on abundance and diversity of aquatic life currently present in the moderate to small creeks it would cross within the investigation area, and has potential to improve fish passage in several creeks. If suggested mitigation measures in Emigrant Creek, Skinners Creek and Byron Creek are implemented (planting of native riparian vegetation, upgrade existing culverts and removal of a causeway), the proposed upgrade would result in improved fish habitat and fish passage.

The proposed upgrade has negligible potential to impact on threatened species, as none are likely to be present in the investigation area. A population of freshwater catfish (*Tandanus tandanus*), a species requiring consideration, was found near where proposed upgrade is aligned in proximity to Emigrant Creek. Potential impacts on this species are considered to be negligible and water quality in the small creek is likely to improve due to the use of sediment basin and sand filtration basins, which would significantly reduce sediment and nutrient loads.

6.0 ACKNOWLEDGEMENTS

This report was authored by Dr Peggy O'Donnell with contributions from Doug Hazell. The following staff undertook field investigations: Peggy O'Donnell, Doug Hazell, Brendan Alderson, Mathew Birch, Kade Mills, and Deirdre Foley. Tables were prepared by Doug Hazell and Peggy O'Donnell. Figures were prepared by Peggy O'Donnell and Brett Maynard.

7.0 REFERENCES

Adam, P., Urwin, N., Weiner, P. and Sim, I. (1985). *Coastal Wetlands of New South Wales.* Prepared for: Coastal Council of New South Wales. Coastal Council of New South Wales, Sydney, NSW.

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Ballina Shire Council (2004). State of Environment Report. Chapter 2: Water.

Bishop, K.A. (1999a). Threatened Fish Species Surveying and Habitat Assessment in the Emigrant Creek Catchment, Richmond River System, NSW. Report in Relation to the Proposed Pacific Highway Upgrade: The Ballina Bypass. Study undertaken for Connell Wagner Pty. Ltd. On behalf of the NSW Roads and Traffic Authority.

Bishop, K.A. (1999b). Revised Eight-Part Test for Three Threatened Freshwater Fish Species. Study undertaken for Connell Wagner Pty. Ltd. On behalf of the NSW Roads and Traffic Authority.

Boxall, A. B. A. and Maltby, L. (1995). The characterization and toxicity of sediment contaminated with road runoff. *Water Research* **29**, pp. 2043-2050.

Boxall, A. B. A. and Maltby, L. (1997). The effects of motorway runoff on freshwater ecosystems .3. Toxicant confirmation. *Archives of Environmental Contamination and Toxicology* **33**, pp. 9-16.

Ellis, J. B., Revitt, D. M. and Llewellyn, N. (1997). Transport and the environment: Effects of organic pollutants on water quality. *Journal of Chartered Institution of Water and Environmental Management* **11**, pp. 170-177.

Faragher R.A., Brown, P. and Harris, J.H. (1993). *Population Surveys of the Endangered Fish Species Trout Cod (Maccullochella macquariensis) and Eastern Cod (M. ikei).* Report for Australian National Parks and Wildlife Service, Endangered Species Program. NSW Fisheries Research Institute, Cronulla.

Fairfull, S. and Witheridge, G. (2003). *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings.* NSW Fisheries, Cronulla, 16 pp.

Krein, A. and Schorer, M. (2000). Road runoff pollution by polycyclic aromatic hydrocarbons and its contribution to river sediments. *Water Research* **34**, pp. 4110-4115.

Lund, M., Davis, J. and Murray, F. (1991). The fate of lead form duck shooting and road runoff in three Western Australian wetlands. *Australian Journal of Marine & Freshwater Research* pp. 139-149.

Maltby, L., Boxall, A. B. A., Forrow, D. M., Calow, P. and Betton, C. I. (1995). The effects of motorway runoff on freshwater ecosystems: 2. identifying major toxicants. *Environmental Toxicology and Chemistry* **14**, pp. 1093-1101.

Maltby, L., Forrow, D. M., Boxall, A. B. A., Calow, P. and Betton, C. I. (1995). The effects of motorway runoff on freshwater ecosystems: 1. field study. *Environmental Toxicology and Chemistry* **14**, pp. 1079-1092.

McNeill, A. and Olley, S. (1998). The effects of motorway runoff on watercourses in south-west Scotland. *Journal of Chartered Institution of Water and Environmental Management* **12**, pp. 433-439.

NPWS (2003). *Ballina Nature Reserve Plan of Management.* NSW National Parks and Wildlife Service, Sydney, NSW.

NSW Fisheries (1999). *Policy and Guidelines; Aquatic Habitat Management and Fish Conservation.* (Eds. Smith, A.K. and Pollard, D.A.), NSW Fisheries, Port Stephens Research Centre, 86pp.

Richardson, B.A. (1985) The impact of forest road construction on the benthic invertebrate and fish fauna of a coastal stream in southern NSW. Australian Society of Limnology Bulletin 10, 65-68.

SKM (2005). Emigrant Creek Water Quality Report (Daft) 18 August 2005. Sinclair Knight Merz 2005.

Storm Consulting (2007a). Pacific Highway Upgrade Tintenbar to Ewingsdale Water Quality Impact Assessment of Chronic Pollutants Report Prepared for: ARUP and the NSW Roads and Traffic Authority July 2007 – Issue A Project No. 651.

Storm Consulting (2007b). Acute Pollution Risk for the Upgrading of the Pacific Highway between Tintenbar and Ewingsdale. Report Prepared for: ARUP and the NSW Roads and Traffic Authority July 2007 –Project No. 651 Issue B.

WBM Oceanics (1999). Pacific Highway Upgrade, Bangalow to St Helena, Water Quality and Hydrology Assessment. 14 April 1999.

Web Reference 1: http://www.fishfiles.fisheries.nsw.gov.au NSW Fisheries fishfiles database website.

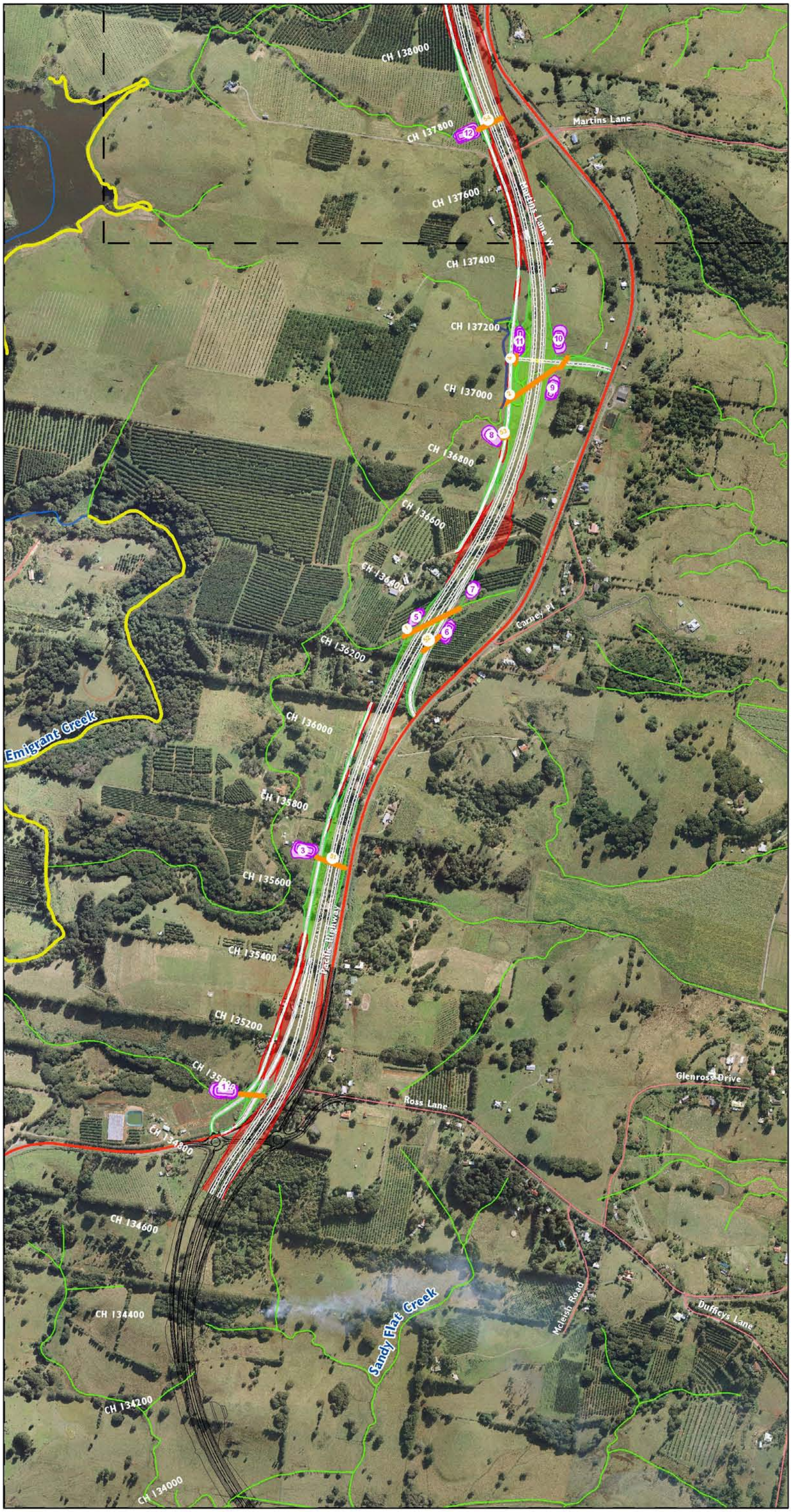
Web Reference 2: http://www.bionet.nsw.gov.au NSW government combined agency biological search database.

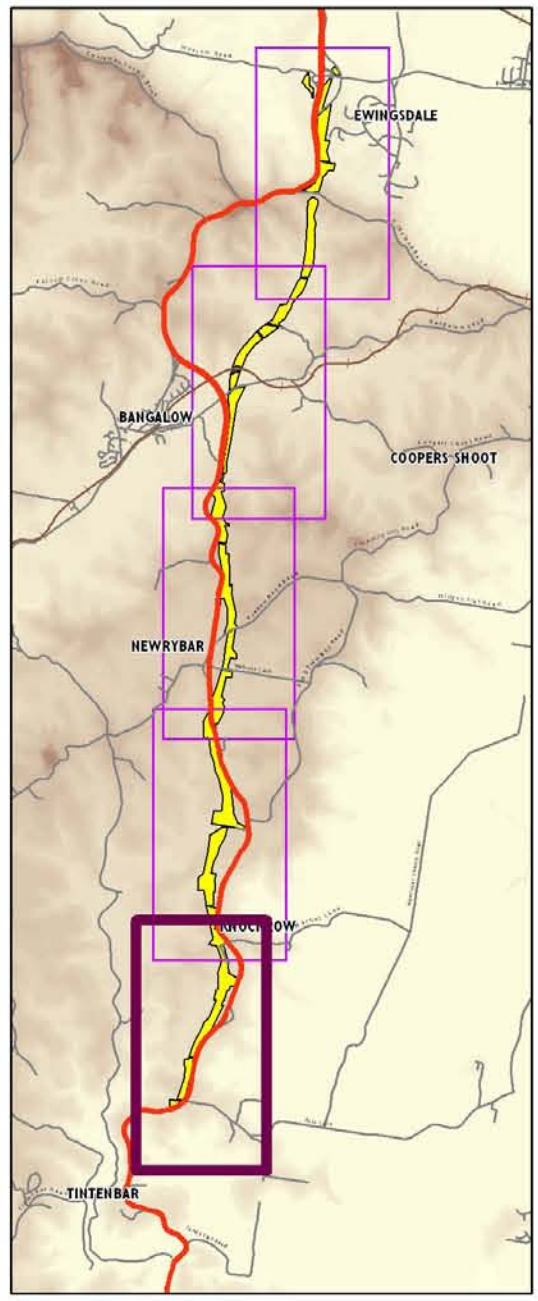
Web Reference 3: http://www.dlwc.nsw.gov.au NSW Department of Land and Water Conservation's 'Estuaries of NSW' and 'Acid Sulfate Soils' websites.

Web Reference 4: http://www.nationalparks.nsw.gov.au/npws.nsf. Department of Environment and Conservation, National Parks and Wildlife website, Threatened species/Key Threatening Processes.

West, R., Thorogood, C., Walford, T. and Williams, R. (1985). *An Estuarine Inventory for New South Wales, Australia.* Division of Fisheries, NSW Department of Agriculture, Sydney, NSW.

FIGURES





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse (indicative only)
- Adjacent Map Extents

Aquatic Ecology

- Minor waterway
- Small creek
- Drainage line
- Creek Diversions

Proposed Upgrade

- Extent of cutting
- Extent of fill
- Drainage Culverts
- Sediment Basins

Environmental Assessment

Proposed Upgrade and Creek Networks

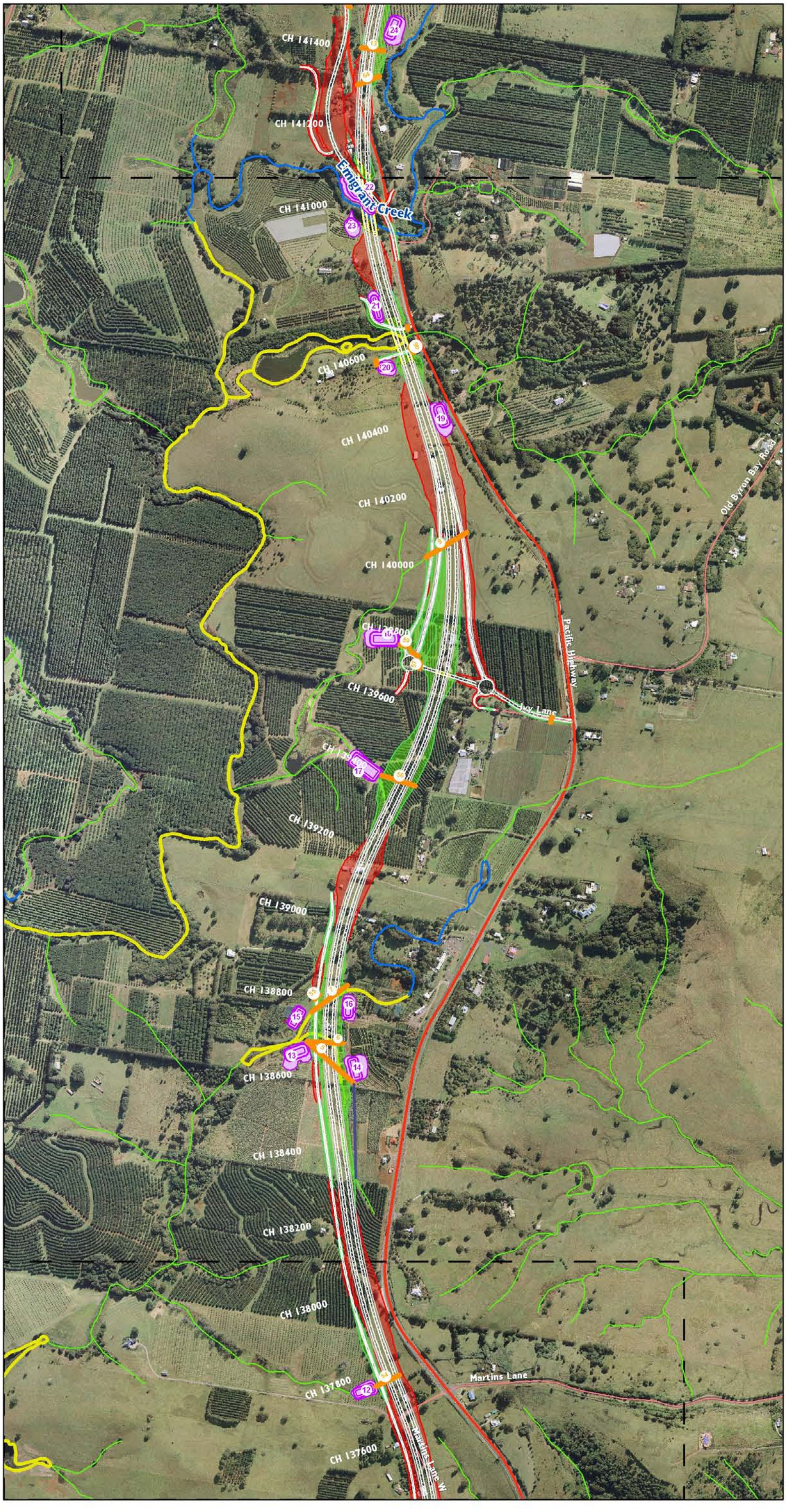
N

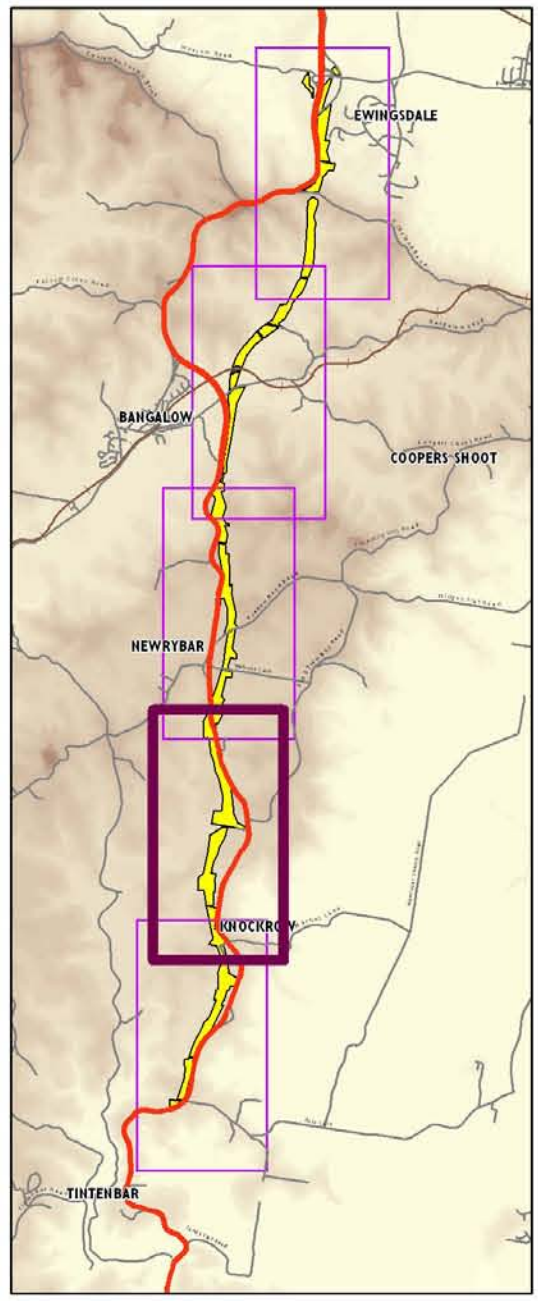
0 100 200 400 Metres

ARUP

RTA

Base: 2000 & 2005 Aerial Photography





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse (indicative only)
- Adjacent Map Extents

Aquatic Ecology

- Minor waterway
- Small creek
- Drainage line
- Creek Diversions

Proposed Upgrade

- Extent of cutting
- Extent of fill
- Drainage Culverts
- Sediment Basins

Environmental Assessment

Proposed Upgrade and Creek Networks

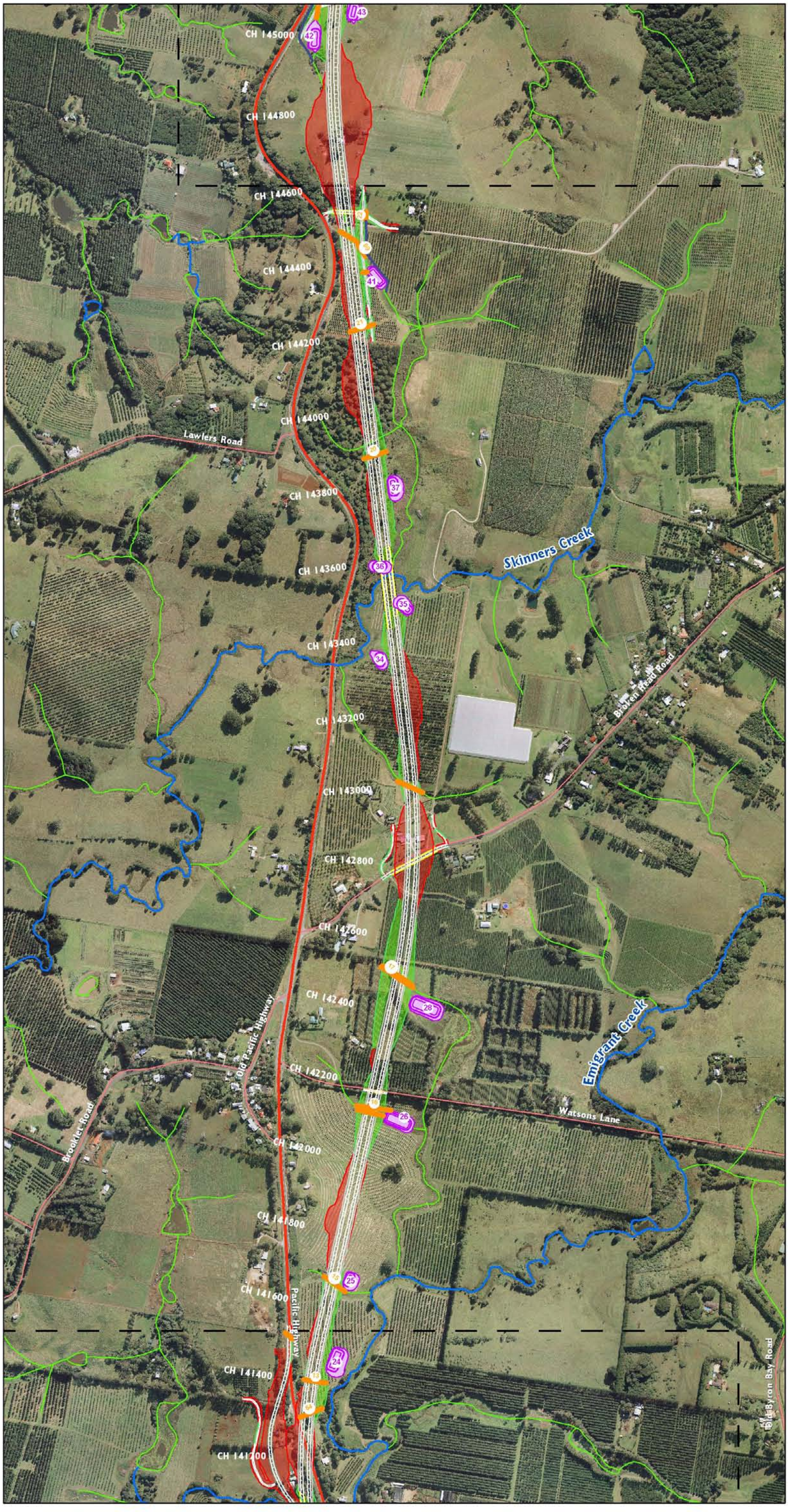
N

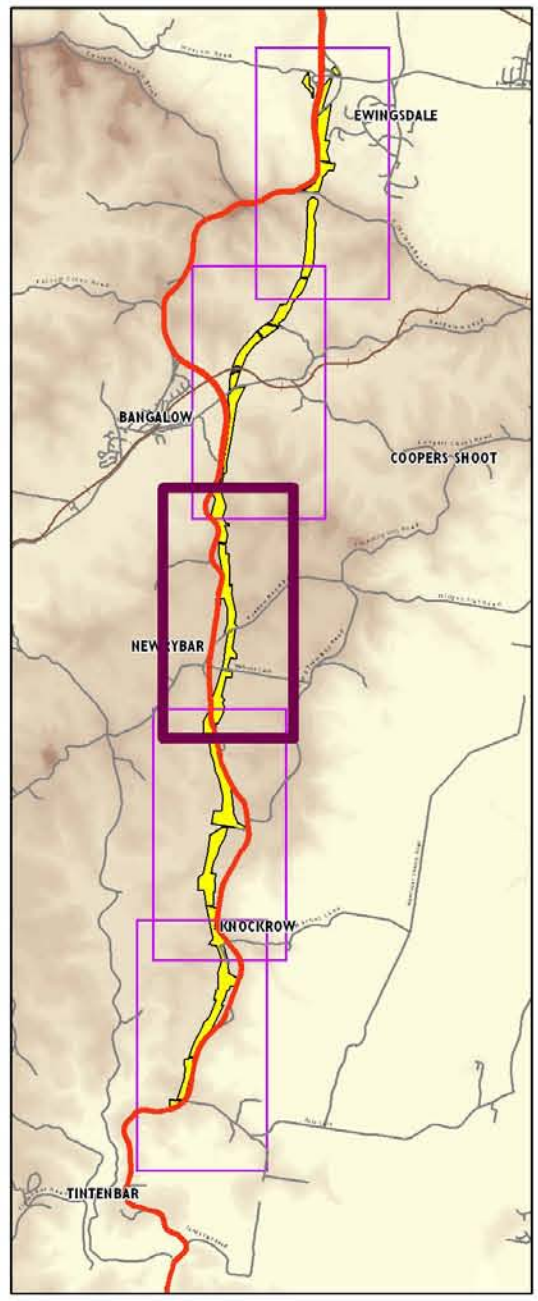
0 100 200 400 Metres

ARUP

RTA

Base: 2000 & 2005 Aerial Photography





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse (indicative only)
- Adjacent Map Extents

Aquatic Ecology

- Minor waterway
- Small creek
- Drainage line
- Creek Diversions

Proposed Upgrade

- Extent of cutting
- Extent of fill
- Drainage Culverts
- Sediment Basins

Environmental Assessment

Proposed Upgrade and Creek Networks

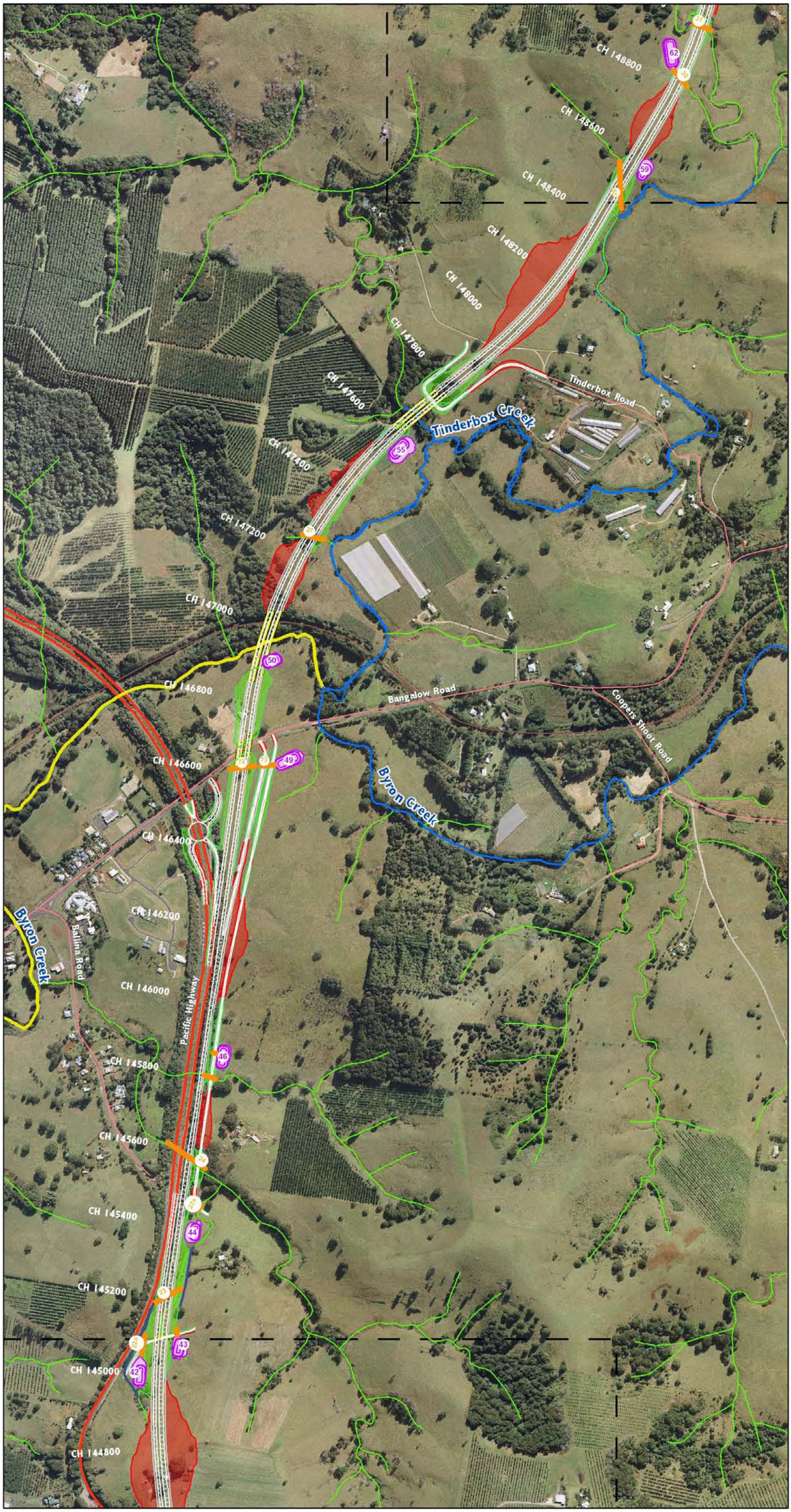
N

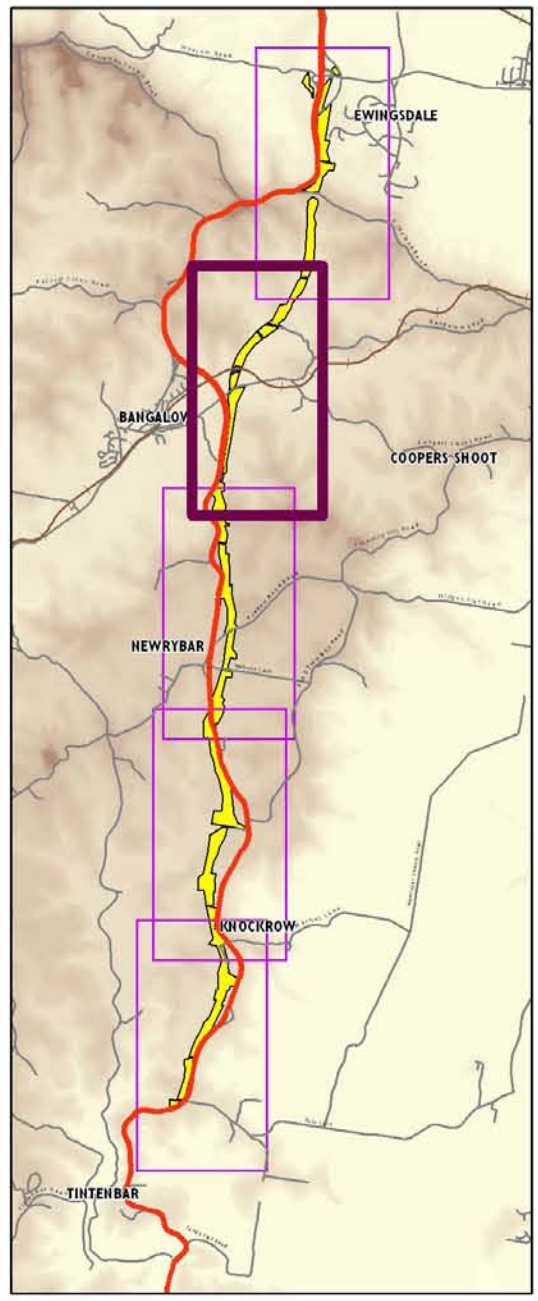
0 100 200 400 Metres

ARUP

RTA

Base: 2000 & 2005 Aerial Photography





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse (indicative only)
- Adjacent Map Extents

Aquatic Ecology

- Minor waterway
- Small creek
- Drainage line
- Creek Diversions

Proposed Upgrade

- Extent of cutting
- Extent of fill
- Drainage Culverts
- Sediment Basins

Environmental Assessment

Proposed Upgrade and Creek Networks

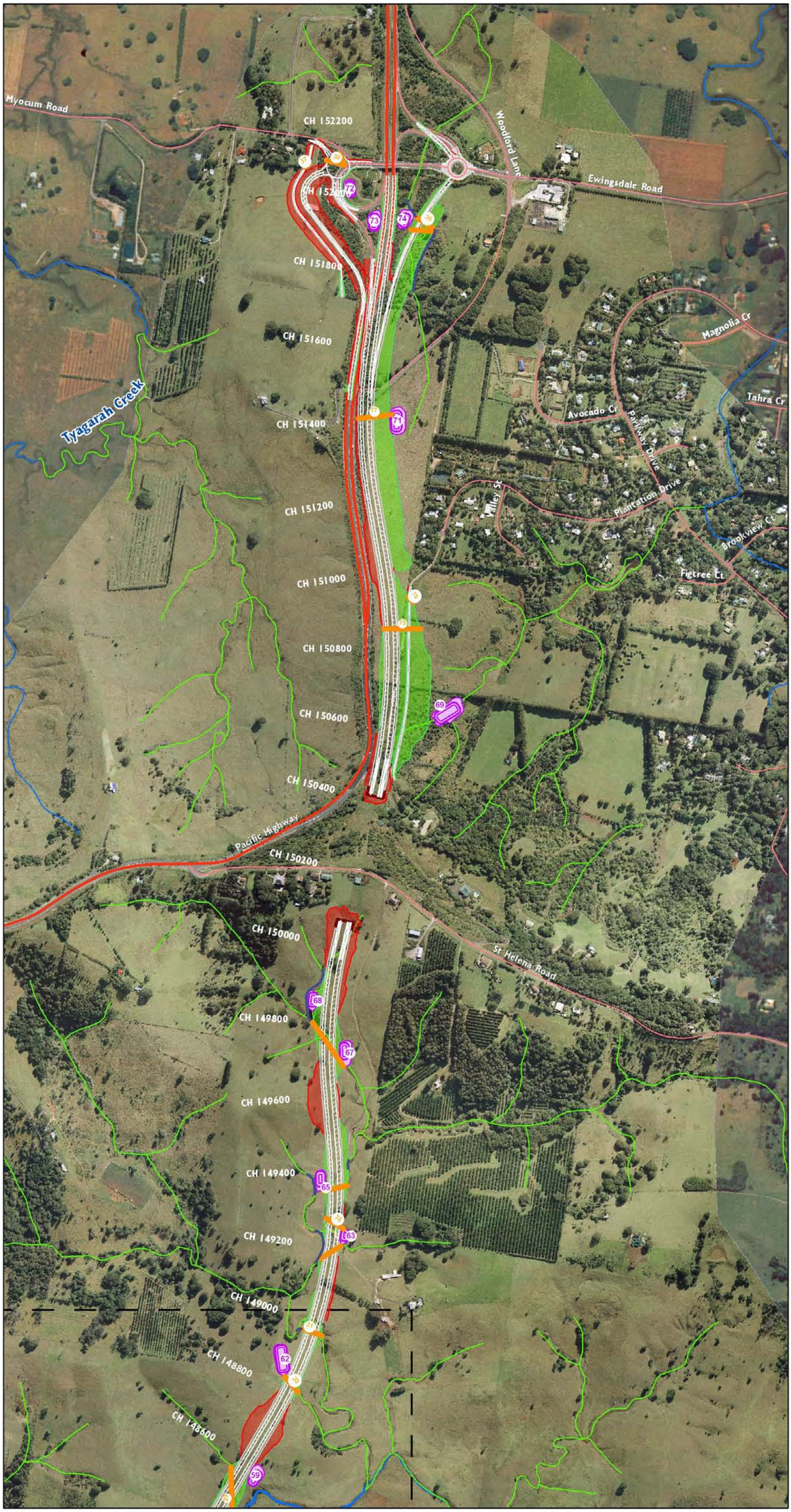
N

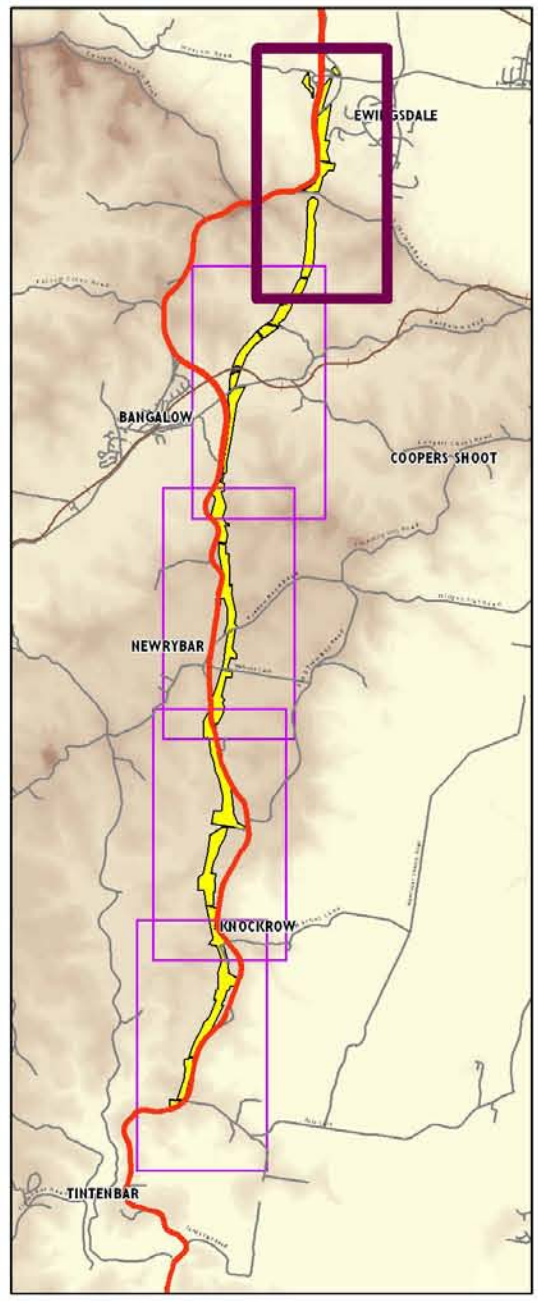
0 100 200 400 Metres

ARUP

RTA

Base: 2000 & 2005 Aerial Photography





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse (indicative only)
- Adjacent Map Extents

Aquatic Ecology

- Minor waterway
- Small creek
- Drainage line
- Creek Diversions

Proposed Upgrade

- Extent of cutting
- Extent of fill
- Drainage Culverts
- Sediment Basins

Environmental Assessment

Proposed Upgrade and Creek Networks

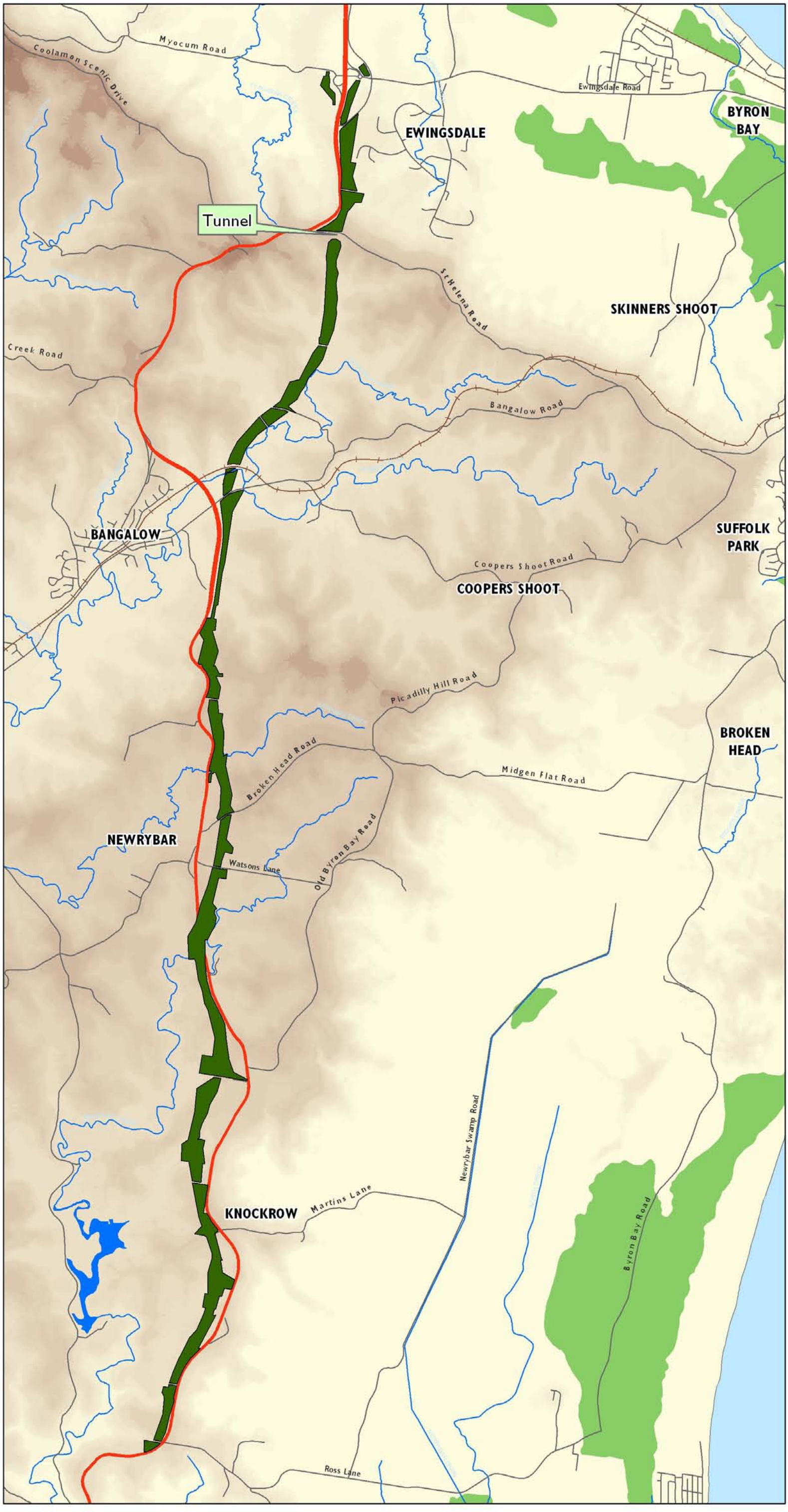
N

0 100 200 400 Metres

ARUP

RTA

Base: 2000 & 2005 Aerial Photography



Legend

- Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse
- SEPP 14 Wetlands

Proposed Upgrade

- Proposed Road Acquisition Boundary

Environmental Assessment

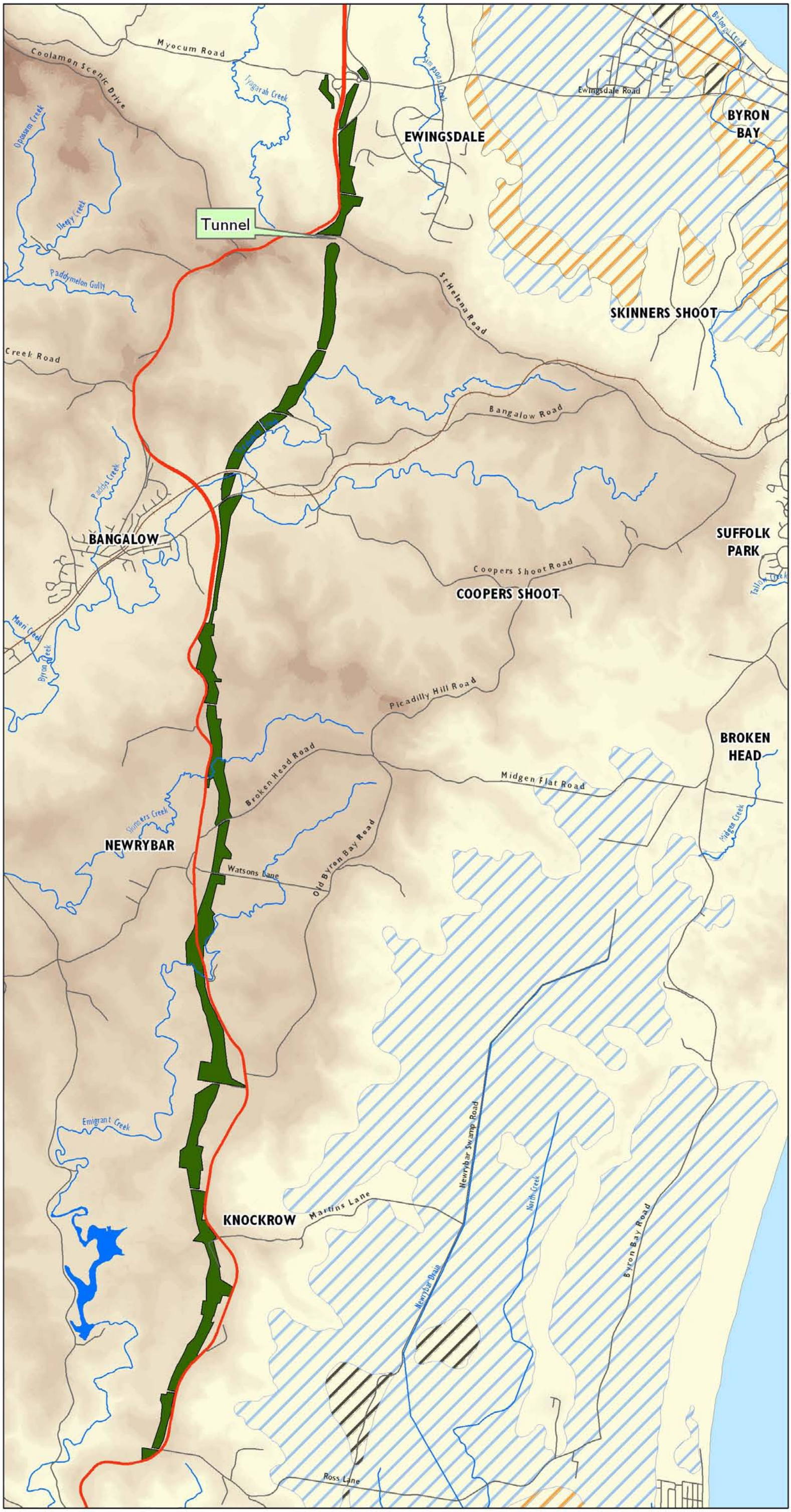
SEPP 14 Wetlands

N

0 0.5 1 2 km

ARUP

RTA



Legend

- Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse

Potential Acid Sulfate Soils

- Disturbed soils
- High risk
- Low risk

Proposed Upgrade

- Proposed Road Acquisition Boundary

Environmental Assessment

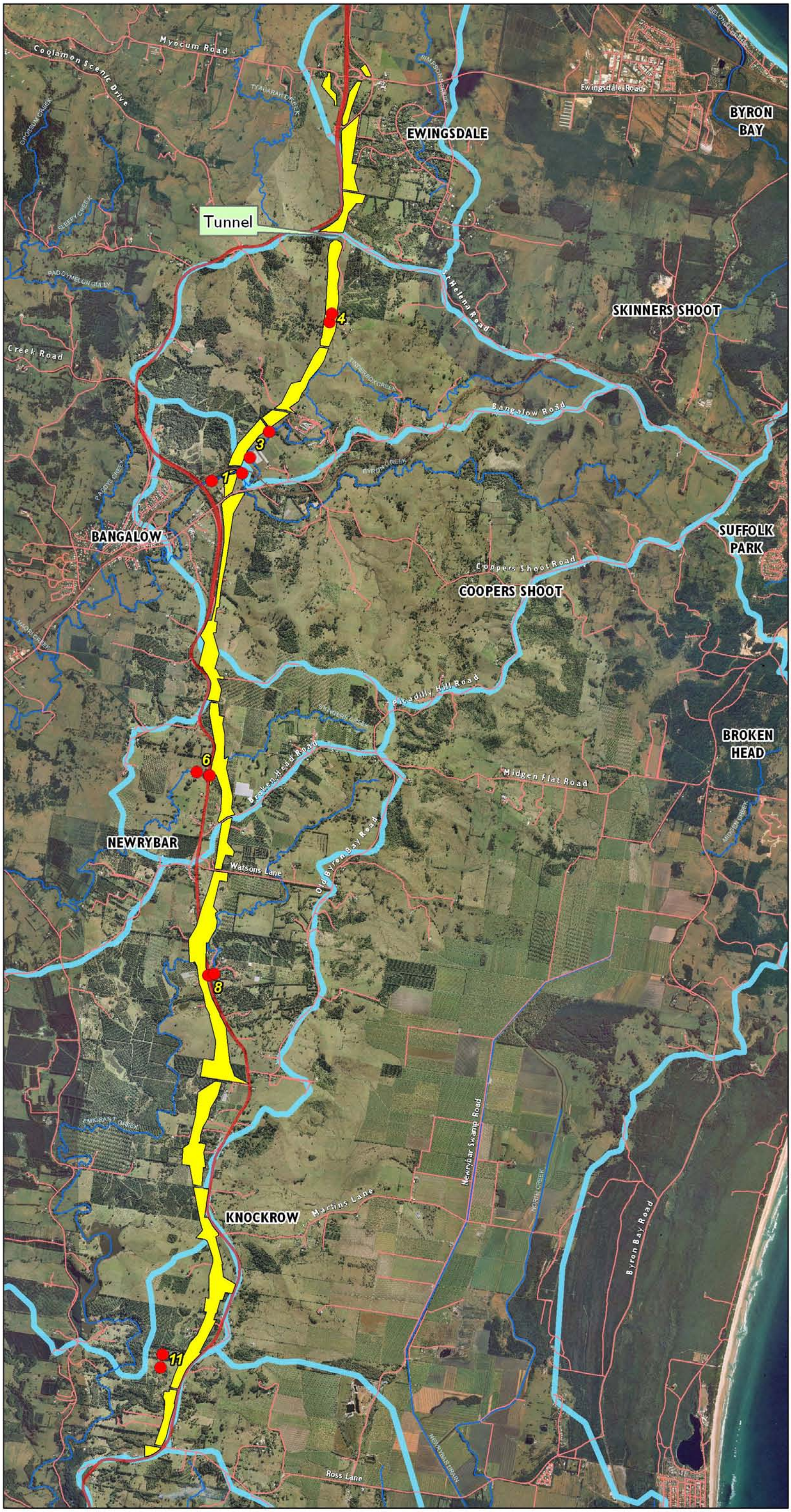
Potential Acid Sulfate Soils

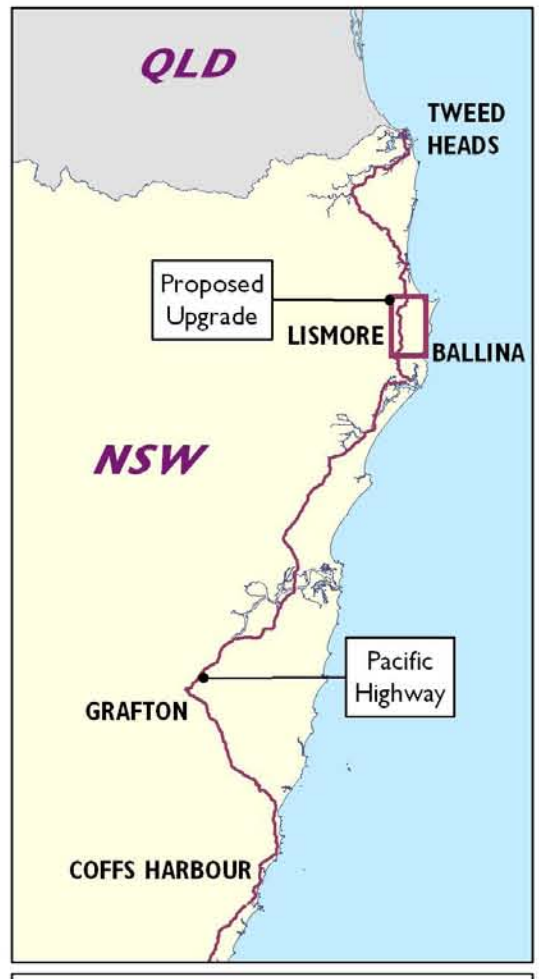
N

0 0.5 1 2 km

ARUP

RTA





Legend

- Existing Pacific Highway
- Regional and Local Roads
- Railway Line
- Major Watercourse
- Catchment Boundary
- 1 ● Fish and mobile macroinvertebrate sampling site (November 2005)

Proposed Upgrade

- Proposed Road Aquisition Boundary

Environmental Assessment

Fish and Mobile Invertebrate Sampling Sites

N

0 0.5 1 2 km

ARUP

RTA

Base: 2000 & 2005 Aerial Photography

TABLES

PLATES

Plate 1 Upper: Emigrant Creek, Yarrenbool, looking downstream.

Plate 1 Lower: Emigrant Creek, Watsons Lane causeway, looking downstream.

Plate 2 Upper: Unnamed tributary of Emigrant Creek, Deenford Plantation, looking upstream.

Plate 2 Lower: Pond on unnamed tributary of Emigrant Creek, Palm Springs fish hatchery, looking upstream.

Plate 3 Upper: Skinner Creek, Pacific Highway crossing, looking downstream.

Plate 3 Lower: Skinners Creek, Singh property, looking upstream.

Plate 4 Upper: Byron Creek, Pacific Highway Bridge, looking upstream.

Plate 4 Lower: Byron Creek, Coopers Shoot crossing (Rankins Dip), looking upstream.

Plate 1 Upper: Emigrant Creek, Yarrenbool, looking downstream.

Plate 1 Lower: Emigrant Creek, Watsons Lane causeway, looking downstream.

Plate 2 Upper: Unnamed tributary of Emigrant Creek, Deenford Plantation, looking upstream.

Plate 2 Lower: Pond on unnamed tributary of Emigrant Creek, Palm Springs fish hatchery, looking upstream.

Plate 3 Upper: Skinner Creek, Pacific Highway crossing, looking downstream.

Plate 3 Lower: Skinners Creek, Singh property, looking upstream.

Plate 4 Upper: Byron Creek, Pacific Highway Bridge, looking upstream.

Plate 4 Lower: Byron Creek, Coopers Shoot crossing (Rankins Dip), looking upstream.

APPENDICES

Appendix 1: Physico-chemical water quality data recorded in situ during site inspections (30 November to 2 December, 2004 and 23 to 26 May, 2005).

Appendix 2: Results of chemical laboratory analyses of water quality samples collected 30 November to 2 December, 2004 and 23 to 26 May, 2005.

Appendix 1: Water Quality Data collected in the study area from 30 November to 2 December, 2004 and 23 to 26 May 2005. Physico-chemical properties recorded in situ using a YeoKal 611 portable multiprobe. Values highlighted in bold indicate that variable is outside of ANZECC (2000) guidelines for protectionof aquatic ecosystems.

	Variable		Temperature (°C)	Conductivity (µs/cm)	pH	ORP (mV)	DO (% sat.)	Turbidity (NTU)
	ANZECC (2000) guidelines for lowland watercourses			125 - 2200	6.5 - 8.0		85 - 110 % sat.	6 - 50
Emmigrant Creek	Site 1	Rep 1	23.35	111	**6.06**	146	**63.2**	24.1
		Rep 2	23.47	105	**5.89**	130	**71.2**	19.1
		Mean	23.41	108	5.98	138	67.2	21.6
		SE	0.06	3	0.08	8	4.0	2.5
	Site 2	Rep 1	24.25	99	**6.23**	323	102.6	**51.2**
		Rep 2	23.62	97	**6.05**	319	97.3	**55.5**
		Mean	23.94	98	6.14	321	100.0	53.4
		SE	0.31	1	0.09	2	2.7	2.2
	Site 3	Rep 1	25.84	93	6.75	233	**139.5**	43.3
		Rep 2	25.44	90	6.60	228	**132.5**	47.1
		Mean	25.64	92	6.68	231	136.0	45.2
		SE	0.20	2	0.08	3	3.5	1.9
	Site 4	Rep 1	24.85	88	**6.37**	225	**81.4**	47.9
		Rep 2	25.01	88	**6.01**	235	**82.3**	**54.0**
		Mean	24.93	88	6.19	230	81.9	51.0
		SE	0.08	0	0.18	5	0.5	3.0
Skinners Creek	Site 5	Rep 1	23.75	113	**6.31**	-58	**50.4**	**220.3**
		Rep 2	25.75	103	**6.06**	11	**127.0**	**268.3**
		Mean	24.75	108	6.19	-24	88.7	244.3
		SE	1.00	5	0.12	35	38.3	24.0
	Site 6	Rep 1	22.60	106	**6.31**	97	**69.4**	20.2
		Rep 2	22.50	106	**6.33**	92	**67.3**	15.5
		Mean	22.55	106	6.32	95	68.4	17.9
		SE	0.05	0	0.01	3	1.1	2.3
Byron Creek	Site 7	Rep 1	25.82	112	6.89	137	**115.1**	20.0
		Rep 2	25.25	112	6.74	137	**116.4**	24.6
		Mean	25.54	112	6.82	137	115.8	22.3
		SE	0.28	0	0.08	0	0.7	2.3
	Site 8	Rep 1	26.22	124	6.90	112	**112.1**	29.1
		Rep 2	26.18	121	6.79	107	110.0	33.3
		Mean	26.20	123	6.85	110	111.1	31.2
		SE	0.02	2	0.06	3	1.0	2.1

Appendix 2: Results of chemical analyses of water sampled collected in the study area from 30 November to 2 December, 2004 and 23 to 26 May 2005. Values highlighted in bold indicate that variable is outside of ANZECC (2000) guidelines for the protection of aquatic ecosystems. Means and standard errors of two

		Emigrant Creek							
	ANZECC (2000) trigger values for lowland watercourses	Site 1		Site 2		Site 3		Site 4	
Analyte		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Organochlorine (OC) Pesticides (ug/L)	various	0	0	0	0	0	0	0	0
Trace metals (mg/L)									
Arsenic	0.05 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Cadmium	0.002 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Chromium	0.05 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.002	0.001
Copper	0.005 mg/L	**0.013**	0.012	0.001	0.000	0.001	0.000	0.001	0.000
Lead	0.005 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Mercury	0.0001 mg/L	1E-04	0	1E-04	0	1E-04	0	1E-04	0
Zinc	0.05 mg/L	0.015	0.007	0.007	0.001	0.002	0.001	0.011	0.002
Chloride (mg/L)	3 mg/L	15	0	14	0	14	0	13	0
Oil and grease (mg/L)		0	0	0	0	0	0	0	0
Sulphate (mg/L)		4	0.1	3.2	0	1.5	0	1.8	0
Suspended soilds (mg/L)		14	8	3.5	1.5	2	0	24.5	19.5
Phosphorus	0.05 mg/L	**0.057**	0.004	0.039	0.000	**0.057**	0.001	**0.125**	0.025
Total Kjeldahl Nitrogen (mg/L)		0.38	0.07	0.35	0.00	1.21	0.90	0.68	0.24
NOx (mg/L)	0.040 mg/L	0.39	0.26	**0.14**	0.09	**0.72**	0.68	**0.13**	0.05
Total Nitrogen (as TKN + Nox)	0.50 mg/L	**0.77**		0.49		**1.93**		**0.81**	

		Skinners Creek				Byron Creek			
	ANZECC (2000) trigger values lowland watercourses	Site 5		Site 6		Site 7		Site 8	
Analyte		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Organochlorine (OC) Pesticides (ug/L)	various	0	0	0	0	0	0	0	0
Trace metals (mg/L)									
Arsenic	0.05 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Cadmium	0.002 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Chromium	0.05 mg/L	0.002	0.001	0.001	0.000	0.001	0.000	0.031	0.030
Copper	0.005 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Lead	0.005 mg/L	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
Mercury	0.0001 mg/L	1E-04	0	1E-04	0	1E-04	0	1E-04	0
Zinc	0.05 mg/L	0.007	0.003	0.011	0.005	0.006	0.003	0.004	0.001
Chloride (mg/L)	3 mg/L	13	0	14	0	15	0	17	0
Oil and grease (mg/L)		0	0	0	0	0	0	0	0
Sulphate (mg/L)		1	0	1.7	0	2.8	0	3.4	0
Suspended soilds (mg/L)		82.5	27.5	3	0	4	1	3	1
Phosphorus	0.05 mg/L	**0.140**	0.070	0.050	0.002	**0.059**	0.003	**0.068**	0.002
Total Kjeldahl Nitrogen (mg/L)		0.99	0.01	0.23	0.00	0.28	0.02	1.05	0.76
NOx (mg/L)	0.040 mg/L	**0.09**	0.08	**0.09**	0.01	**0.16**	0.14	0.36	0.32
Total Nitrogen (as TKN + Nox)	0.50 mg/L	**1.08**		**0.31**		0.43		**1.41**	